STUDIES ON THE CHEMICAL SEED TREATMENT OF GRASSES

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

Page

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INTRODUCTION

Historical Review

Four general methods of control of plant diseases are recognized, viz. exclusion, eradication, protection, and immunization. Seed treatment may be either an eradicative or protective measure, or both. The organic mercury dusts, for example, are both eradicants and protectants.

The history of seed treatment extends back as far as the latter part of the 17th century when the brining method for the control of bunt of wheat was accidentally discovered. Since then, other materials besides common salt, such as lime, saltpetre, and wood ashes, have been used. However, it was not until 1761 that an intelligent application of chemical seed treatment was made. Schulthuss (23, 25, 27) suggested the use of copper sulphate in place of common salt for seed treatment purposes. It was not generally used, however, until after 1858 when Kühn (23, 25, 27) made definite recommendations from the results of his

extensive experiments. This treatment, although controlling bunt of wheat, was found to cause considerable seed injury. This disadvantage was partially overcome when the treated seed was dipped in a lime solution.

In 1895 Geuther (23, 25) in Germany, and in 1896 Bolley (23, 25) in the United States, advocated the use of formaldehyde for the prevention of cereal smut diseases. It soon replaced copper sulphate and became quite popular due to its cheapness and effectiveness. Its main disadvantage was that, while controlling covered smuts of cereals, it tended to injure the seed rather seriously. Even today it is, perhaps, the most widely used chemical for the treatment of seed grain in western Canada.

In 1902 Von Tubeuf (23) introduced the first successful dust fungicide in the form of copper carbonate dust. It was not, however, until 1915, following successful experiments made by Darnell-Smith (23, 25, 27) in Australia, that it came into much prominence. Five years later Mackie and Briggs (23, 27) introduced it to the United States. Advantages, such as ease of application and non-injurious action on seed, which this treatment seemed to have over other treatments at once placed it in the forefront. It is still used today in many places as a standard treatment for the control of bunt of wheat.

Kellerman and Swingle (27) tested mercuric chloride, a powerful bactericide, for the treatment of cereal grains

but without success. This apparently was the first time a mercury compound had been used for seed treatment. Hiltner (27) found that it was valuable for the control of Fusarium disease of rye and a number of preparations such as "Fusariol" and "Fusafine" containing mercuric chloride were marketed. About 1912 mercuric chloride, because of its highly poisonous properties, was being replaced for pharmaceutical purposes by organic mercury compounds. Such compounds were found in medicine to combine high efficiency in destroying bacteria and spores with little or no tendency to injure body tissue. Those interested in seed treatment problems were naturally attracted by the properties of this new group of compounds, and Wesenberg (23, 27) was the first to suggest the use of such chemicals as seed fungicides.

Martin (27) points out that, "true organo-mercury derivatives are those in which the mercury atom is attached direct, by one or both valency bonds, to carbon atoms. The general structure of those derivatives found as the active constituents of seed disinfectants is R.Hg.X. where R represents a hydrocarbon with or without substituent groups, and X represents an acidic radical".

The first person to use an organic mercury compound for seed treatment was Riehm (23, 25, 27) who carried out extensive tests with chlorophenol mercury and reported successful control of bunt in 1913. This compound is a

chemical combination of mercury and carbolic acid, suitable for use only when dissolved or suspended in water. It was marketed in Germany under the trade name "Uspulun", and in 1921 a similar compound called "Chlorophol" was sold in the United States.

Numerous other compounds, mostly for liquid treatment, were experimented with but failed to attain commercial success because of inconsistent effectiveness, seed injury, or excessive cost.

Organic mercury compounds for dry seed treatment were first tested experimentally in the United States in 1922, about ten years after Riehm's first work. In 1924 a commercial compound called "Uspulun Dry Dressing" (a mercurized nitrophenol compound) was manufactured in Germany, and a similar compound called "Semesan" appeared in the United States in 1925. Other dust compounds such as Germisan (cresyl mercuric cyanide), Bayer Dust (hydroxymercurinitrophenol sulphate), Sterocide (mercury furfuramid), Semesan Jr. (hydroxymercuricresol), Semesan (hydroxymercurichlorophenol sulphate), and Merko (3.5% metallic-mercury in an inert filler) were also used to a considerable extent.

Further impetus was given to the seed treatment investigations by the introduction of alkyl and aryl mercury salts. These were many times more efficient as fungicides, against the smuts of wheat, oats, and barley,

than the original mercurated phenols. This group contains such commercial products as "European" Ceresan (phenyl mercury acetate), Agrosan G. (tolyl mercuric acetate), "American" Ceresan (ethyl mercury chloride), Standard Leytosan (methyl mercury nitrate), Leytosan P (methyl mercury phosphate), ½ oz. Leytosan (methyl mercury carbamide), New Improved Ceresan (ethyl mercury phosphate), and Lunasan (ethyl mercury thiourea).

The use of such compounds, although very efficient at first, was very expensive as the recommended rate of application was two to three ounces per bushel but, upon further study, some of these compounds such as Ceresan were found to be volatile, giving off germicidal vapours. Because of this fact it was found that such a volatile fungicide could be applied at one-half ounce per bushel and still be effective. The cost of seed treatment with these organic mercury compounds was thus reduced, permitting them to be used more extensively.

In the development of organic mercury compounds there has been a marked decrease in the metallic mercury content. The original compound "Uspulun" contained 18.8% metallic mercury, while later ones such as "Ceresan" contain only 3.8% metallic mercury. This indicates that the fungicidal properties are not all due to the metallic mercury content as has been demonstrated by Dillon Weston and Booer (6).

At present there are, on the market in Canada, three organic mercury dusts commonly used for the treatment of cereal grains, viz. Ceresan, $\frac{1}{2}$ oz. Leytosan, and Lunasan. Information on the composition et cetera, of these and other preparations used in these studies is given in the following list.

List of chemical compounds used in these studies

Compound	Trade name	Manufacturer	Percentage active ingredient	Percentage inert ingredient	Mercury equivalent
Ethyl Mercury Phosphate	New Improved Ceresan (Ceresan)	Bayer-Semesan Company, Inc. U.S.A.	5.0	95.0	3.8
Methyl Mercury Phosphate	Leytosan P	F.W.Berk & Co. Ltd. London, England	--	--	3.0
Methyl Mercury Carbamide	$\frac{1}{2}$ oz.Leytosan	F.W.Berk & Co. Ltd. London, England	--	--	4.0
	Seed disinfectant No. IV/39	F.W.Berk & Co. Ltd. London, England	--	--	--
	Seed disinfectant No. 1155-I.W.	Bayer-Semesan Company, Inc. U.S.A.	--	--	--
Ethyl Mercury Thiourea	Lunasan	Lunvale Products Ltd. Queens Mill, Lancaster, England	4.0	96.0	2.3
Para-Amino-benzene-Sulfonamide	Sulfanilamide N.N.R.	Mallinckrodt Chemical Works, U.S.A.	--	--	--
Formaldehyde	Formalin	Standard Chemical Co. Montreal, Quebec	40.0 (approx.)	60.0	--

Objects of the Investigations

These investigations were conducted in order to determine the effects, both beneficial and injurious, of certain fungicides on some of the grass seeds. The principal objects were to determine:

1. The effect of chemical seed treatment on germination and disease prevention in lawn and forage grasses
2. The relative injurious effects of different organic mercury dusts on wheat
3. The relative reactions of different varieties of wheat to treatment with an organic mercury dust.

THE EFFECT OF CHEMICAL SEED TREATMENT ON GERMINATION AND DISEASE PREVENTION IN LAWN AND FORAGE GRASSES

Introduction

"It is quite possible that, besides other important functions we might develop methods of treatment of seed other than disease preventing measures, which would add

materially to the crop yield of the country and to the national wealth".--Harrington (17).

Many grasses are known to have inferior germination which presents a difficult problem for agronomists. The methods now used to increase germination are chiefly of a mechanical or physical nature, such as scarifying the impermeable seed coat or membrane, and the use of alternating temperatures. Toole (42) was successful in germinating Kentucky blue grass seed by alternating the temperatures daily during the period of germination. Hite (21) found that Canada blue grass, without light or alternating temperatures, germinated only 25%, and Kentucky blue grass 60%. She found that alternating temperatures were beneficial for both and that light was essential for Canada blue grass germination. Hulless timothy seed is also known to have very poor germination. Goss (13), for instance, showed that it germinated 17% less than the hulled seed and that 72% of the seed tested was hulless, which indicates the seriousness of the problem. Newton and Ficht (32) also mention a similar problem in the production of timothy in Alberta.

The use of chemicals has apparently had little or no part in the attempt to promote germination of grass seed. In official seed testing laboratories, a 2% potassium nitrate solution is often used to promote germination. Apart from this, there appears to be little available

literature on the effect of the use of chemicals for the purpose of improving the germination of grass seed. Chippindale (2) in 1934, noticing the marked beneficial effect of seed treatment with Ceresan in the case of cereals in practical agriculture, thought it advisable to determine exactly the action of this substance on grass seeds since the germination of the latter in the field is often unsatisfactory. He experimented with indigenous cocksfoot (_Dactylis glomerata_), tall fescue (_Festuca elatior_), and red fescue (_Festuca rubra_), and found there was no evidence of stimulated germination. However, he concluded that the application of Ceresan to grass seeds, previous to their being sown in the field, might often be markedly beneficial in practical farming, the value of such application being that it would protect the seed during unfavorable germinating conditions.

Weimer (43) treated seeds of Kentucky blue grass and timothy with indolebutyric acid and found no stimulating action. She pointed out, however, that even the most lethal poison can be used as a valuable therapeutic agent if taken at the proper time in the proper dosage, and that indolebutyric acid may be just such a potential chemical. Incidentally, no reference was found in which favorable effects of chemical seed treatment on the germination of timothy seed were cited.

However, there are reports of chemical treatment of the seed of perennial grasses for the control of disease.

Fraser and Scott (12) found that the use of formaldehyde would control smut (*Ustilago bullata* Berkeley) of slender wheat grass (*Agropyron pauciflorum* Schwein. Hitchc.) but that copper carbonate dust would not. The same pathogen also causes a smut of prairie grass (*Bromus unioloides*) which Morwood (30) claimed is effectively controlled by applying abavit B or Ceresan at the rate of three ounces per twenty pounds of seed. Smut was reduced from 83.5% to 0.1% by such treatments. He also found that formaldehyde effectively controlled the smut but that it reduced the germination as well. Henry *et al* (20) found that smut (*U. bullata*) of slender wheat grass could be effectively controlled by the use of organic mercury dusts applied at the rate of one-half ounce per bushel.

Preliminary Experiments

Experiment I

Seed of several lawn grasses was available in the laboratory, having been obtained previously from a commercial seed house. It was necessary, at the outset, to determine the percentage germination of these samples of seed.

Methods

The seed was sown on the top of sand of optimum moisture content in 9 cm. Petri plates. There was a single

plate of 100 seeds for each grass. The plates were kept at room temperature with plenty of light available. Germination counts were made every two days, the germinated seeds removed, and water added when necessary.

Results

The percentage germination of each sample of grass seed available for these studies is presented in Table I:

TABLE I

Percentage germination of available seed samples of several species of grass seed

Grass	% germination
Creeping Bent (*Agrostis palustris*)	82
Canada Blue (*Poa compressa*)	10
Chewing's Fescue (*Festuca rubra var. commutata*)	37
Red Fescue (*Festuca rubra*)	33
Kentucky Blue (*Poa pratensis*)	19
Brown Top (Colonial Bent) (*Agrostis tenuis*)	82
Red Top (*Agrostis alba*)	94

It will be observed that the seed samples of *Poa* and *Festuca* species are very low in germination, especially the *Poa* species. Kentucky blue grass, because of its low germination, was selected for further experiments in an

attempt to increase the germination by chemical seed treatment. Kentucky blue grass is a common component of lawn and pasture mixtures, but it is sometimes difficult to get established due to its low germination.

Experiment II

This was a preliminary experiment to determine the effect of organic mercury dusts on the germination of Kentucky blue grass.

Methods

The organic mercury dusts, Ceresan, ½ oz. Leytosan, Leytosan P, and Lunasan, were diluted with talc to give a 2% concentration of the active ingredient in each case. The dusts were applied in excess and the surplus removed by means of a fine silk screen. The treated seed was then allowed to stand for 24 hours prior to sowing. The treatments were in quadruplicate and the seed was sown under the same conditions as in Experiment I. Notes were taken on the germination each week for six weeks and the germinated seeds removed. At the end of this period, notes were also taken on the number of mouldy seeds present.

Results

The percentage germination and percentage mouldy seeds are given in Table II.

TABLE II

Effect of chemical seed treatment on Kentucky blue grass

Treatment	% germination	% mouldy
Check	24.2	11.0
Lunasan 2%	11.2	0.5
Ceresan 2%	12.5	0.2
$\frac{1}{2}$ oz. Leytosan 2%	4.0	0.2
Leytosan P 2%	18.0	1.8

The results show that the organic mercury dusts at 2% concentration did not increase the germination but, on the contrary, appear in each case to have seriously injured the seed. This is no doubt due to the excess application of dust and shows that the concentration of the active ingredient in the dust used was too great for this method of treating or that the dust should be applied in smaller quantities. The interesting point of the experiment, however, is the reduction of the number of mouldy seeds in the treated lots. This indicates that if the dusts were applied at the proper concentrations and rates, there might be a beneficial effect on germination. This would be especially likely in the case of unfavorable germination conditions, as pointed out by Chippindale (2).

Experiment III

This was an experiment to determine the effect of various chemicals on the emergence* of Kentucky blue grass in sterilized and unsterilized soils.

Methods

The same treatments were used as in Experiment II, plus sulfanilamide at four concentrations: 5, 10, 20, and 100%. The dusts were applied in the same manner and the seed left for 24 hours before sowing. The seed was sown in six-inch pots containing a three to one black loam-sand mixture. One-half of the pots were sterilized prior to sowing, for eight hours at fifteen pounds steam pressure, while the other half were left unsterilized. The treatments were in quadruplicate, randomized, and the pots placed on a greenhouse bench at ordinary greenhouse temperature. The pots were placed in large galvanized trays and watered from the bottom to avoid disturbing the seed. After seven weeks, notes were taken on the emergence.

Results

Table III presents the emergence for the various treatments, and Table IV shows the variance for emergence.

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* In these studies "emergence" means that the seed has been covered and that the seedling appears above the ground level, while "germination" means that the seed has not been covered and the seedling appears directly.

TABLE III

Effect of chemical seed treatment on the emergence of Kentucky blue grass in sterilized and unsterilized soil

Treatment	% emergence Sterilized	Unsterilized
Check	24.2	23.8
Ceresan 2%	23.2	33.8
½ oz. Leytosan 2%	16.0	35.8
Lunasan 2%	24.5	31.2
Leytosan P 2%	15.0	6.2
Sulfanilamide 5%	32.8	31.0
Sulfanilamide 10%	23.5	28.8
Sulfanilamide 20%	19.0	4.5
Sulfanilamide 100%	16.2	24.2
Minimum significant difference	7.39	7.39

TABLE IV

Variance for emergence data of Kentucky blue grass treated with various chemicals and sown in sterilized and unsterilized soil

Source of variance	D.F.	Mean square	F	5%	1%
Treatments	8	439.08	2.04	2.13	2.89
Soils	1	136.12	0.63	4.03	7.17
Treatments x Soils	8	214.88	7.83	2.13	2.89
Error	51	27.47			
Total	71				

Although the results are extremely variable as indicated by the highly significant interaction of treatments x soils, there is an indication that some of the treatments

are beneficial in the unsterilized soil. The lower emergence percentages and greater variability found in the sterilized soil are due to the fact that the sterilized soil did not take up water very readily. The differences due to treatments were not significant because the very high mean square of the interaction was used in determining the F value. The results obtained with Ceresan, $\frac{1}{2}$ oz. Leytosan, and Lunasan in the unsterilized soil show definite increases in emergence over the check, but not so in the sterilized soil. The only treatment to show definite increases in emergence in both the sterilized and unsterilized soil was that made with sulfanilamide 5%. This is interesting in view of the therapeutic action of sulfanilamide in medicine.

Experiment IV

This was an additional test to determine the effect of various chemicals on the emergence of Kentucky blue grass.

Methods

These were similar to those of Experiment III except that only unsterilized soil was used. The formaldehyde treatment consisted of dipping the seed, held in small cheese-cloth bags, into the formaldehyde solution for two minutes, then draining and covering for four hours before drying and sowing. The seed was sown in small cardboard boxes containing a three to one black loam-sand mixture.

The treatments were quadruplicated, randomized and the boxes placed on a greenhouse bench, with ordinary greenhouse temperature prevailing.

Results

The average percentage emergence is presented in Table V, while the results of the analysis appear in Table VI.

TABLE V

Effect of chemical seed treatment on the emergence of Kentucky blue grass

Treatment	% emergence
Check	22.5
Formaldehyde 1-320	12.8
Formaldehyde 2-320	11.0
Sulfanilamide 5%	8.5
Sulfanilamide 10%	11.5
Sulfanilamide 20%	11.5
Sulfanilamide 100%	13.2
Du Bay 1155-I.W. 100%	1.2
Berk IV/39 100%	7.5
Lunasan 2%	10.2
Lunasan 100%	5.0
½ oz. Leytosan 2%	9.5
½ oz. Leytosan 100%	7.8
Ceresan 2%	20.0
Ceresan 100%	2.2
Leytosan P 100%	21.2
Minimum significant difference	5.00

TABLE VI

Variance for emergence data of Kentucky blue grass treated with various chemicals

Source of variance	D.F.	Mean square	F	5%	1%
Treatments	15	151.05	6.05	1.97	2.61
Error	45	24.98			
Total	63				

The differences due to treatments are significant beyond the 1% point, which is due to the fact that in nearly every case the seed was severely injured, and consequently the emergence lowered. The action of sulfanilamide in this experiment is the reverse of that in the previous experiment and cannot be explained.

The Effect of Various Concentrations of Ceresan, Applied at Different Rates, on the Emergence of Kentucky Blue Grass

In the preliminary experiments, an attempt was made to use organic mercury dusts diluted with talc to 2% of their active ingredients, applying them in excess so that each seed was covered. This proved unsatisfactory as it generally caused severe seed injury. It was, therefore, decided to increase the number of concentrations by diluting with varying amounts of talc and applying the dust at definite rates.

Methods

Ceresan was diluted with talc to give concentrations of 0, 1, 2, 3, 4, and 5% ethyl mercury phosphate, which is the active ingredient. The seed was then treated at the following rates: one part dust to 50, 100, 300, 600, and 1000 parts of seed for each of the above concentrations. There was also an untreated check and a check using talc alone at each of the above rates. The treatment of the seed was done in 10-gram lots, in 200 cc. rubber-stoppered Erlenmeyer flasks. The seed was left 24 hours before counting into lots of 100 seeds each, and then sown in small cardboard boxes containing a three to one black loam-sand mixture. The treatments were quadruplicated, randomized, and the boxes placed on a greenhouse bench at prevailing greenhouse temperatures. To eliminate border effect as much as possible, a row of extra boxes was placed all round the outer edge of the group of experimental boxes. After four weeks notes were taken on the emergence.

Results

The summary tables are presented in Appendix I and the variance for the emergence data is given in Table VII.

TABLE VII

Variance for emergence data of Kentucky blue grass treated with various chemicals

Source of variance	D.F.	Mean square	F	5%	1%
Concentrations	5	46.23	2.86	2.32	3.23
Rates	4	85.84	5.31	2.47	3.53
Concentrations x rates	20	11.02	0.68	1.64	2.00
Error	87	16.16			
Total	119				

Table VII shows that the differences due to concentrations are significant beyond the 5% point and those for rates are significant beyond the 1% point. The interaction of concentrations x rates is not significant. Therefore, there is no consistent beneficial or injurious effect of Ceresan on the emergence of Kentucky blue grass. There are, however, some treatments that do show a beneficial effect over both the untreated check and the talc check, the talc check being the 0% concentration.

The Effect of Chemical Seed Treatment on the Control of the Leaf Spot and Foot Rot Disease of Kentucky Blue Grass Caused by *Helminthosporium vagans*

Introduction

Helminthosporium vagans (Drechs) (9) is a common parasite of Kentucky blue grass, causing a disease character-

ized by the production of numerous lenticular lesions on the above-ground parts of the plants, particularly on the leaves. In badly infected areas the plants may die due to the parasite girdling the plants at the base or foot, cutting off the flow of nutrients. This is termed foot rot. The disease is quite common and may be serious on fairways of golf courses or on lawns where close and frequent clipping is the common practice. It is common in this locality but is usually not destructive.

Methods

The parasite Helminthosporium vagans was isolated from diseased plants of Kentucky blue grass found on the University campus. The pathogenicity was checked by inoculating Kentucky blue grass plants in pots in the greenhouse. These plants later showed leaf spot and foot rot symptoms. The inoculum for this experiment was produced on a medium consisting of black loam soil plus 10% cornmeal. This inoculum was produced in 200 cc. Erlenmeyer flasks, each containing 50 grams of the air-dry soil-cornmeal mixture plus 27 cc. of tap water. These flasks were sterilized for two hours at 15 pounds steam pressure, and the contained medium then sown with Helminthosporium vagans from potato dextrose agar slants. The fungus was allowed to grow for approximately three weeks at room temperature, by which time the mycelium had completely penetrated the substrate.

The pots in which the seed was to be sown were sterilized for eight hours at 15 pounds steam pressure. A three to one black loam-sand mixture was used. The seed was treated with Ceresan at the concentrations and rates which appeared to be most beneficial in the previous experiment. The pots were divided into two groups; one half were infested with the fungus and the other half left as a check. Inoculum was placed at seed level in the pots and added at the rate of 25 grams per pot. The treatments were in duplicate and randomized. The pots were then placed on a greenhouse bench with ordinary greenhouse temperatures prevailing. After three months, notes were taken on the number of surviving plants and also on the number of diseased plants. A plant was considered diseased if it showed any lesions or signs of foot rotting.

Results

Table VIII presents the percentage survival and percentage of diseased plants recorded.

TABLE VIII

The effect of chemical seed treatment on the control of the leaf spot and foot rot disease of Kentucky blue grass caused by *Helminthosporium vagans*

Treatment	% survival	% diseased
Check not inoculated	17.5	0.0
Check inoculated	3.5	0.5
Ceresan 5% 1-300 check	16.5	0.0
Ceresan 5% 1-300 inoculated	5.5	0.5
Ceresan 5% 1-100 check	22.0	0.0
Ceresan 5% 1-100 inoculated	9.0	1.5
Ceresan 3% 1-300 check	16.5	0.0
Ceresan 3% 1-300 inoculated	5.5	1.5
Ceresan 3% 1-100 check	15.0	0.0
Ceresan 3% 1-100 inoculated	12.5	2.5
Ceresan 5% 1-600 check	14.0	0.0
Ceresan 5% 1-600 inoculated	8.0	2.5
Ceresan 3% 1-600 check	12.0	0.0
Ceresan 3% 1-600 inoculated	3.5	2.0

The results show that Ceresan, at the concentrations and rates used, does not effectively control the leaf spot and foot rot disease of Kentucky blue grass. Some of the higher applications, however, seemed to increase the percentage survival of plants in the inoculated series, particularly 3% Ceresan applied at the rate of 1-100.

The Effect of Various Concentrations of Ceresan Applied at Different Rates on the Emergence of Crested Wheat Grass (*Agropyron cristatum* (L.) Beauv.)

Methods

The same methods as for the similar experiment on Kentucky blue grass were used. The seed was taken from the 1940 crop which had just been threshed. After four weeks, notes were taken on emergence.

Results

Summarized tables of the percentage emergence are presented in Appendix II. Variance for the emergence data appears in Table IX.

TABLE IX

Variance for emergence data of crested wheat grass treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Concentrations	5	126.65	2.54	2.32	3.23
Rates	4	65.18	1.30	2.47	3.53
Concentrations x rates	20	60.72	1.22	1.64	2.00
Error	87	49.95			
Total	119				

The differences due to concentrations are significant beyond the 5% point, while the differences due to rates

are not significant. The interaction of concentrations x rates is not significant, so there is no beneficial effect of Ceresan on the emergence of crested wheat grass. There is, however, a slight benefit from the diluent alone, that is the talc. The fact that the seed had been only freshly harvested and threshed may account for the low emergence figures and also explain why the Ceresan tended to reduce the emergence regardless of concentration or rate applied.

The Effect of Various Concentrations of Ceresan Applied at Different Rates on the Emergence of Hulled and Hulless* Timothy Seed (*Phleum pratense* (L.))

Methods

The methods were the same as for the experiment with crested wheat grass, except that the hulled and hulless seeds were separated after treatment and sown separately. Emergence notes were taken two weeks after sowing.

Results

Hulless seed: The summary tables of the percentage emergence are presented in Appendix III. The variance for the emergence data appears in Table X.

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* In these studies the term "hulled" describes seed which has retained the protective hull (lemma and palea) and "hulless" describes seed which has lost this protective hull.

TABLE X

Variance for emergence data of hulless timothy seed treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Concentrations	5	1770.42	1.22	2.71	4.10
Rates	4	9072.62	6.27	2.87	4.43
Concentrations x rates	20	1446.82	23.07	1.70	2.09
Error	87	62.71			
Total	119				

The differences due to concentrations are not significant, while the differences due to rates are significant beyond the 1% point. The interaction of concentrations x rates is highly significant. The mean square for the interaction was used in calculating the F values rather than the mean square for error. From these results, it appears that there is a beneficial effect produced by Ceresan on the emergence of hulless timothy seed and that the rate of application is a far more important consideration than the concentration used. There is serious seed injury when the dust is applied at the higher rates. The application of talc alone increased the emergence on the average approximately 12%.

Hulled seed: The summary tables for the percentage emergence are presented in Appendix IV. The variance for the emergence data is given in Table XI.

TABLE XI

Variance for emergence data of hulled timothy seed treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Concentrations	5	3017.67	1.66	2.71	4.10
Rates	4	14565.78	8.03	2.87	4.43
Concentrations x rates	20	1814.24	84.90	1.70	2.09
Error	87	21.37			
Total	119				

The differences due to concentrations are not significant, while the differences due to rates and the interaction of concentrations x rates are both highly significant, particularly the latter. There is a marked beneficial effect produced by the Ceresan on the emergence of hulled timothy seed, although severe injury occurs at the higher rates of the stronger concentrations. Talc apparently has a beneficial effect over the check lots, but the differences are not significant.

These results, for both hulless and hulled timothy seed, were analysed on the basis of percentage emergence. According to Clark and Leonard (3) this is not considered to be statistically correct as it tends to give false results. They suggest that data such as these, which show large differences, should be converted to the sine of the angle θ. This conversion reduces the differences by increasing the size of the smaller values and by reducing the size

of the larger values. For this reason it was thought advisable to carry out this conversion on these data and determine the effect which it might have on the analysis. It was important to know this as most of the data presented in this paper were taken on a percentage basis. The percentages were, therefore, converted to the sine of the angle θ from tables given by Bliss (1). The variance for the converted emergence data appears in Table XII for the hulless, and in Table XIII for the hulled seed.

TABLE XII

Variance for converted emergence data of hulless timothy seed treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Concentrations	5	738.57	1.09	2.71	4.10
Rates	4	4526.02	6.66	2.87	4.43
Concentrations x rates	20	679.18	25.78	1.70	2.09
Error	87	26.34			
Total	119				

TABLE XIII

Variance for converted emergence data for hulled timothy seed treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Concentrations	5	1476.36	1.55	2.71	4.10
Rates	4	7948.21	8.36	2.87	4.43
Concentrations x rates	20	951.01	52.25	1.70	2.09
Error	87	18.20			
Total	119				

Comparing Table X with XII, and Table XI with XIII, it will be seen that the differences are slight and unimportant. The interaction of concentrations x rates in the case of the hulled seed has been reduced by the conversion, but it still remains highly significant.

On the basis of the above comparisons, it was decided that nothing would be gained by converting all the percentage data into the sine of the angle θ, since the percentage figures in this experiment show more variability than in any others. Hence, if conversion to the sine of the angle θ is unnecessary here, it should be still less necessary in the other experiments.

The Effect of Various Concentrations of ½ oz. Leytosan Applied at Different Rates on the Emergence of Hulled and Hulless Timothy Seed

Methods

The fungicide used here, namely, ½ oz. Leytosan, was diluted with various amounts of talc to obtain concentrations of 0, 1, 2, 3, and 4% methyl mercury carbamide, the active ingredient. The methods were similar to those used in previous experiment on timothy.

Results

Hulless seed: The summary tables of the percentage emergence figures are presented in Appendix V. The variance for the emergence data is given in Table XIV.

TABLE XIV

Variance for emergence data of hulless timothy seed treated with $\frac{1}{2}$ oz. Leytosan

Source of variance	D.F.	Mean square	F	5%	1%
Concentrations	4	1970.52	4.95	3.01	4.77
Rates	4	2483.30	6.24	3.01	4.77
Concentrations x rates	16	398.08	1.90	1.89	2.45
Error	72	209.88			
Total	99				

The differences due to concentrations and to rates are significant beyond the 1% point while the interaction of concentrations x rates is barely significant at the 5% level. The application of $\frac{1}{2}$ oz. Leytosan produced an increase in the emergence of hulless timothy seed, and in no case was there severe seed injury. Talc did not increase the emergence over that of the check lots. Appendix V indicates that 4% $\frac{1}{2}$ oz. Leytosan applied at the rate of 1 - 50 parts per weight of seed is the best treatment.

Hulled seed: The summary tables of the percentage emergence are presented in Appendix VI. The variance for emergence data appears in Table XV.

TABLE XV

Variance for emergence data of hulled timothy seed treated with ½ oz. Leytosan

Source of variance	D.F.	Mean square	F	5%	1%
Concentrations	4	343.86	1.54	3.01	4.77
Rates	4	232.32	1.04	3.01	4.77
Concentrations x rates	16	223.70	3.91	1.89	2.45
Error	72	57.20			
Total	99				

The differences due to concentrations and to rates are not significant but the interaction of concentration x rates is highly significant. There is thus a beneficial effect produced by ½ oz. Leytosan on the emergence of hulled timothy seed. There is some seed injury produced when the stronger concentrations are applied at the higher rates. Treatment with 2% concentration of ½ oz. Leytosan applied at the rate of 1-100 parts by weight of seed gave best results. The application of talc gave a slight increase in emergence over that of the check lots.

The Effect of Temperature on Treated and Untreated Hulless Timothy Seed

Methods

Since hulless timothy seed responded more to treatment with organic mercury dusts than other grass seeds

tested, it was chosen for this experiment. The seed was treated with 3% Ceresan at the rate of one part dust to 300 parts of seed, because this treatment had produced the greatest increase in emergence in previous tests. The seed was sown in Petri plates containing black loam soil at optimum moisture, 100 seeds per plate. There were also check plates. The treatments were replicated five times, and the plates were placed in constant temperature cabinets maintained at the following temperatures: 10, 15, 20, 25, and 30°C. Although thermostatically controlled, the temperatures of the cabinets were checked daily during the time of the experiment, which was approximately ten days.

Results

The summary tables of the percentage emergence data are presented in Appendix VII. The variance for the emergence data is given in Table XVI. The results are also illustrated in Figures I and II.

TABLE XVI

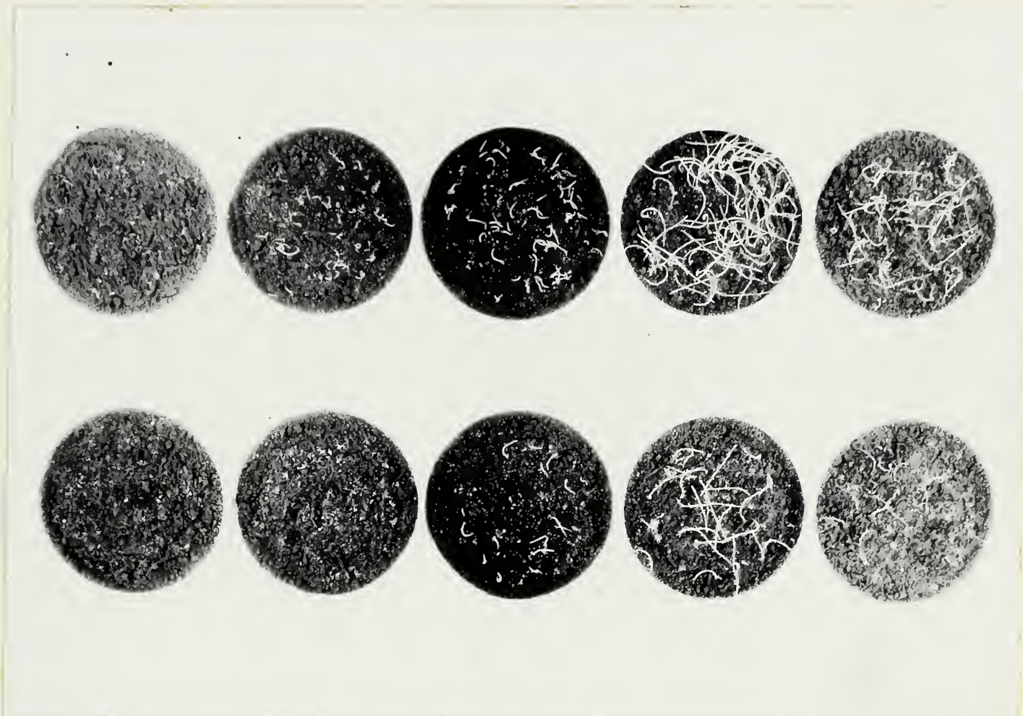
Variance for emergence data of treated and untreated hulless timothy seed at different temperatures

Source of variance	D.F.	Mean square	F	5%	1%
Treatments	1	19365.12	177.55	7.71	21.20
Temperatures	4	390.13	3.58	6.39	15.98
Treatments x temperatures	4	109.07	3.49	2.64	3.91
Error	36	31.21			
Total	49				

The differences due to treatments are significant beyond the 1% point, which was expected from previous results. The differences due to temperatures are not significant but the interaction of treatments x temperatures is significant beyond the 5% level. Therefore, the treatments act differently at different temperatures, the check emerging best at 15°C and the treated at 25°C.

FIGURE I

The effect of temperature on the emergence of treated and untreated hulless timothy seed



After six days.

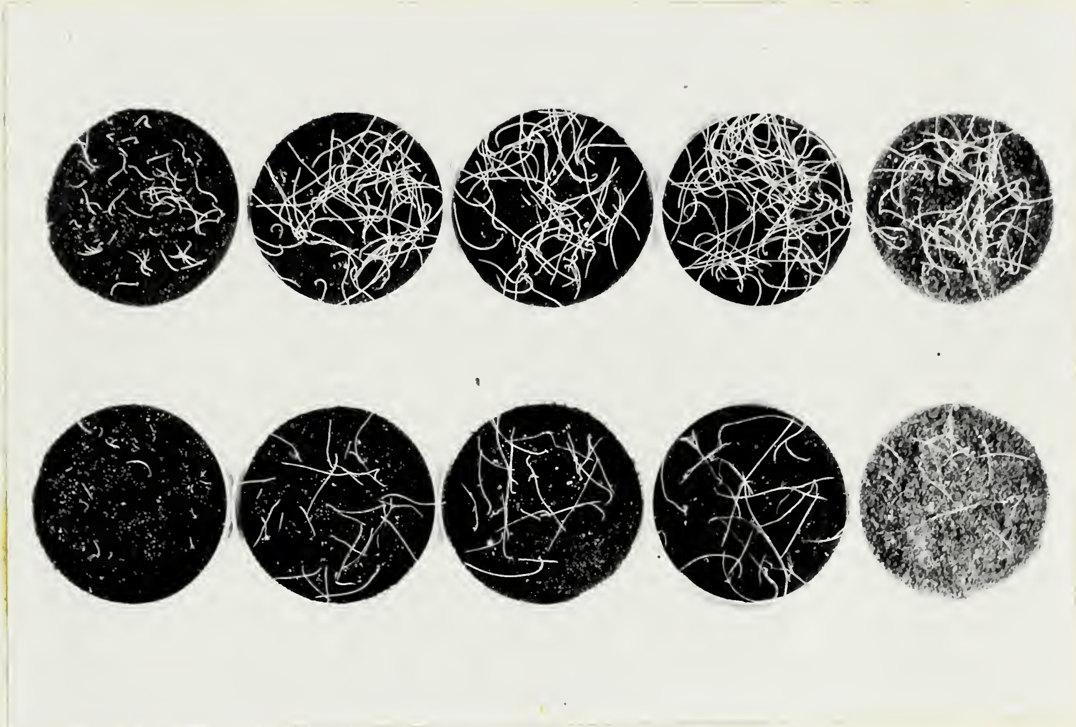
Upper row: Treated with 3% Ceresan at 1-300.

Lower row: Untreated.

Left to right: Temperatures 10, 15, 20, 25, and 30°C.

FIGURE II

The effect of temperature on the emergence of treated and untreated hulless timothy seed



After 10 days.

Upper row: Treated with 3% Ceresan 1-300.

Lower row: Untreated.

Left to right: Temperatures 10, 15, 20, 25, and 30°C.

THE RELATIVE AMOUNT OF SEED INJURY IN WHEAT CAUSED BY VARIOUS ORGANIC MERCURY DUSTS

Introduction

"The aim in seed disinfection is to kill all disease infection and at the same time not injure the vitality of the seed. The perfect seed disinfectant has not yet been found, but important advances in that direction have been made in recent years".(23)

Within the past fifteen years there has been a marked shift from the use of liquid to dust fungicides for seed treatment purposes. Organic mercury dusts have found most favor as seed fungicides within the past ten years. This has been particularly noticeable since the development and adoption of volatile mercury dusts. One of the advantages claimed for organic mercury dusts is that they cause a minimum of seed injury, and often improve emergence. However, a number of cases have been reported in which considerable seed injury occurred from the use of organic mercury dusts.

In 1932 Rabien (37) reported that farmers using abavit B, a mercurial fungicide, in a certain German district, had suffered losses due to seed injury. Neill (31)

in 1934 found that when Ceresan was applied at forty times the normal rate, germination was practically inhibited. New Improved Ceresan also applied in excess caused severe seed injury, but not as great as Ceresan. The application of superphosphate tended to reduce the injury. Later workers also reported seed injury caused by Ceresan. Crosier (4), on testing a sample of Marquis wheat which had been treated with Ceresan and stored for a year, found that many of the kernels germinated abnormally. On the basis of 300 seeds, 51% were abnormal--13% developing short, thickened roots, 34% very mishapen plumules and roots, and 4% failing to germinate. Work carried on at the Geneva experimental station (8) showed that Ceresan, when applied to moist wheat seed, commonly caused abnormal germination, at least 50% of the seeds being so weakened that the seedlings consisted of short, clubbed roots and plumules.

Seed treated with Ceresan or New Improved Ceresan and stored even for a week resulted in some depression in yield, and longer storage resulted in still greater injury, in tests made by Koehler in Illinois (23). Similar results were obtained by Hanna in Manitoba, especially when the moisture content of the seed was high (16). MacDonald (26) treated normal wheat seed at 3, 6, and 42 times the regular rate, with Ceresan and Agrosan G. The latter gave only slight reduction in germination, while the former reduced the germination approximately 50% at the highest application.

New Improved Ceresan, according to Porter (35), caused severe seed injury to barley, sorghum, and corn.

Reports of seed injury caused by treatment of seed with organic mercury compounds led to investigations on the nature of such seed injury. In 1938 Noll (33), working in Uruguay, found after intensive histological and cytological studies that the abnormalities resembled those due to the application of colchicine. The tumor formation found in the coleoptiles and roots is induced by hypertrophy of the existing cells rather than by an increase in their number. These giant cells contain from two to eight nuclei and are nearly always present in the outgrowths. Similar results were reported by Sass (38) in corn. In this plant the leaf primordia undergo extensive thickening and develop irregular crenations and lobes. Cell division in both the leaf primordia and apical meristem is inhibited and extreme enlargement of the existing cells takes place. The cells of the hypertrophied organs become multinucleate, containing nuclei ranging from minute micro-nuclei to polyploid giant nuclei the number of chromosomes of which may exceed two hundred. Kostoff (24), working with five species of wheat and rye, was able to double the number of chromosomes by germinating the seeds in 0.5 to 1% Granosan (ethyl mercury chloride) solutions for three to six days. Studying the abnormal seedlings, he found abnormal mitosis similar to that induced by colchicine and acenaphthene,

namely, failure of (rather abnormal) achromatic figures, chromosome multiplications, multinucleations, and formation of large amoeboid nuclei.

The object of the present work was to determine whether there was any seed injury caused by the organic mercury dusts commonly used in western Canada for treating seed wheat and, if so, under what environmental conditions it would occur. It was necessary to determine this since a study of the varietal reaction to seed injury caused by organic mercury dusts was contemplated, and a suitable fungicide was needed.

General Methods

The seed was placed in 200 cc. Erlenmeyer flasks, closed with rubber stoppers. In order to promote seed injury, the seed was raised to approximately 14% moisture before treating. After 24 hours the seed was treated with an organic mercury dust at the following rates: 0, $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, and 3 ounces per bushel. The flasks were then tightly stoppered and left for 24 hours before seeding.

In the greenhouse the seed was sown in small cardboard boxes, $4\frac{1}{2}$" x 3 3/8" x $1\frac{1}{4}$", containing either sand or a three to one black loam-sand mixture. Each box was sown with 25 healthy, normal seeds at a depth of three-quarters of an inch. The treatments were randomized and

replicated five times. The seeded boxes were placed on a greenhouse bench with ordinary greenhouse temperatures prevailing. To prevent the outer boxes from drying out, a row of boxes was placed round the outside as a border. In two weeks' time, notes were taken on emergence, plant height, and number of injured seeds.

In the field, the seed was sown at the rate of 200 seeds per rod row, with a border row on each side. The seed was sown at a depth of about $1\frac{1}{2}$ inches in rows 9 inches apart. The treatments were randomized and replicated five times. When the plants were mature, a foot was trimmed off each end of the centre row to eliminate border effect, and the rest of the row was then harvested and wrapped with cotton cloth. Notes were taken on emergence and yield.

The results were analysed by Fisher's method (10) as described by Goulden (15) and the level of significance was determined by means of Snedecor's table for values of F and t (40).

Experiment I

Methods

A variety of wheat, Regent, was treated as indicated under General Methods, with each of three organic mercury dusts--Ceresan, $\frac{1}{2}$ oz. Leytosan, and Lunasan-- and sown in sand in the greenhouse. The treatments were not randomized so the results could not be analysed statistically by Fisher's method.

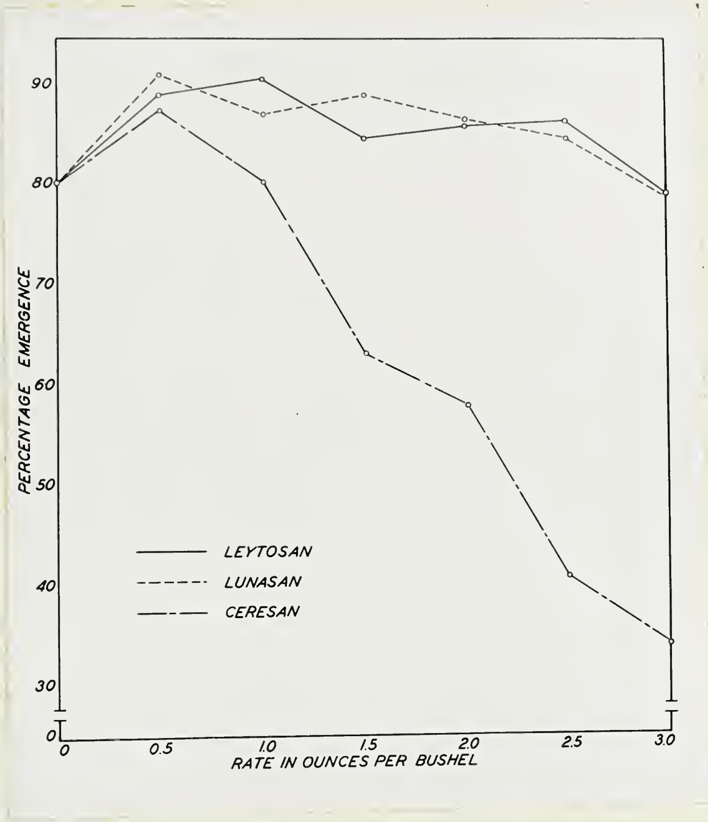
Results

The summary tables showing emergence, plant height, and the number of injured seeds, are presented in Appendix VIII. Figure III illustrates graphically the effect of the treatments on emergence. The plants were also measured and the average height for each box, as well as the number of injured seeds per box, was noted. These figures, on the whole, gave a much better index of the effects of seed treatment on wheat than did the emergence alone. The same trend is shown by each of the measurements but together they give the most complete picture.

The striking thing about this experiment is the effect Ceresan has upon the seed, especially when overdoses are used, as compared with the effects of the other two dusts. However, an increase in the percentage emergence occurred for each dust when applied at the recommended rate. The increase in height brought about by $\frac{1}{2}$ oz. Leytosan and Lunasan is probably due in part to the fertilizing effect of these compounds, as well as to their fungicidal effect. In general, the results indicate that, when overdoses were used, Ceresan caused more seed injury than $\frac{1}{2}$ oz. Leytosan or Lunasan. It was, therefore, decided to use Ceresan in future experiments to determine the relative responses of different wheat varieties to treatment with an organic mercury dust.

FIGURE III

The relative amount of seed injury caused by various organic mercury dusts sown in sand in the greenhouse



Experiment II

This experiment was conducted in an effort to determine the action of the various organic mercury fungicides under field conditions. The methods of preparing the seed were the same as for the previous experiment.

Results

The summary tables containing the percentage emergence and yield data are presented in Appendix IX. The variance for the emergence and yield data is given in Table XVII and Table XVIII, respectively.

TABLE XVII

Variance for emergence data of wheat treated with various organic mercury dusts

Source of variance	D.F.	Mean square	F	5%
Dusts	2	45.74	0.52	3.88
Rates	6	130.20	1.48	3.00
Dusts x rates	12	88.21	2.52	1.88
Error	80	35.04		
Total	104			

Emergence: The differences due to the dusts and rates are not significant. The interaction of dusts x rates is significant to the 5% level only, which indicates that the different dusts act differently for the different rates of application. It will be seen from the summary table that all treatments except Lunasan at three

ounces per bushel increased the percentage emergence which was not the case in the greenhouse experiment. It appears then that seed injury does not necessarily occur if the treated seed is sown in the field under favorable conditions.

TABLE XVIII

Variance for yield data of wheat treated with various organic mercury dusts

Source of variance	D.F.	Mean square	F	5%
Dusts	2	151.38	1.62	3.11
Rates	6	126.17	1.35	2.21
Dusts x rates	12	91.09	0.97	1.88
Error	80	93.69		
Total	104			

<u>Yield</u>: The differences due to dusts, rates, and the interaction of dusts x rates are not significant. This would indicate that there was insufficient seed injury to reduce the yield. The general trend is towards an increase in yield from the treated seed.

<u>Experiment III</u>

This experiment was designed to check the contradictory results obtained in the two previous experiments.

<u>Methods</u>

The variety, Regent, was treated in the same manner as before and sown in both sand and a three to one

black loam-sand mixture. The height data were based on the average emergence of the plants in the check boxes in each case. The total height of the plants from each box in each treatment was divided by the average emergence for the check boxes in the case of each fungicide.

Results

The summary tables of the emergence and height data are presented in Appendix X. The variance for the emergence and height data is given in Tables XIX and XX, respectively. The results are shown graphically in Figures IV and V, while Figure VI is a photograph showing the effects of the various fungicides.

TABLE XIX

Variance for emergence data of wheat treated with various organic mercury dusts

Source of variance	D.F.	Mean square	F	5%	1%
Dusts	2	736.90	4.78	3.88	6.93
Media	1	6.88	0.37	5.99	13.74
Rates	6	111.17	0.72	3.00	4.82
Dusts x Media	2	18.65	3.64	3.06	4.75
Dusts x rates	12	154.18	30.11	1.82	2.31
Media x rates	6	18.34	3.58	2.16	2.92
Dusts x media x rates	12	5.81	1.13	1.82	2.31
Error	164	5.12			
Total	209				

Emergence: The differences due to dusts are significant beyond the 5% level. The differences due to media and rates are not significant. All the first order inter-

actions are significant especially dusts x rates, which shows that there is a differential response. The different dusts react differently for different rates and also different media. The different rates used reacted differently with the different media. Ceresan is the only one of the three dusts to cause any seed injury, but it will be noticed that the injury does not occur until the rate of application exceeds one ounce per bushel. The other fungicides--½ oz. Leytosan and Lunasan--tend to increase the emergence at all rates of application. The beneficial effect of treatment is much more apparent in soil than in sand. This is no doubt due to the greater number and variety of microorganisms present in the soil which interfere with the untreated seed.

TABLE XX

Variance for height data of wheat treated with various organic mercury dusts

Source of variance	D.F.	Mean square	F	5%	1%
Dusts	2	1040.98	6.71	3.88	6.93
Media	1	625.40	21.05	5.99	13.74
Rates	6	113.86	0.73	3.00	4.82
Dusts x media	2	13.30	2.76	3.06	4.75
Dusts x rates	12	155.08	32.17	1.82	2.31
Media x rates	6	29.71	6.16	2.16	2.92
Dusts x media x rates	12	5.49	1.14	1.82	2.31
Error	164	4.82			
Total	209				

FIGURE IV

The relative amount of seed injury in wheat caused by various organic mercury dusts in sand in the greenhouse

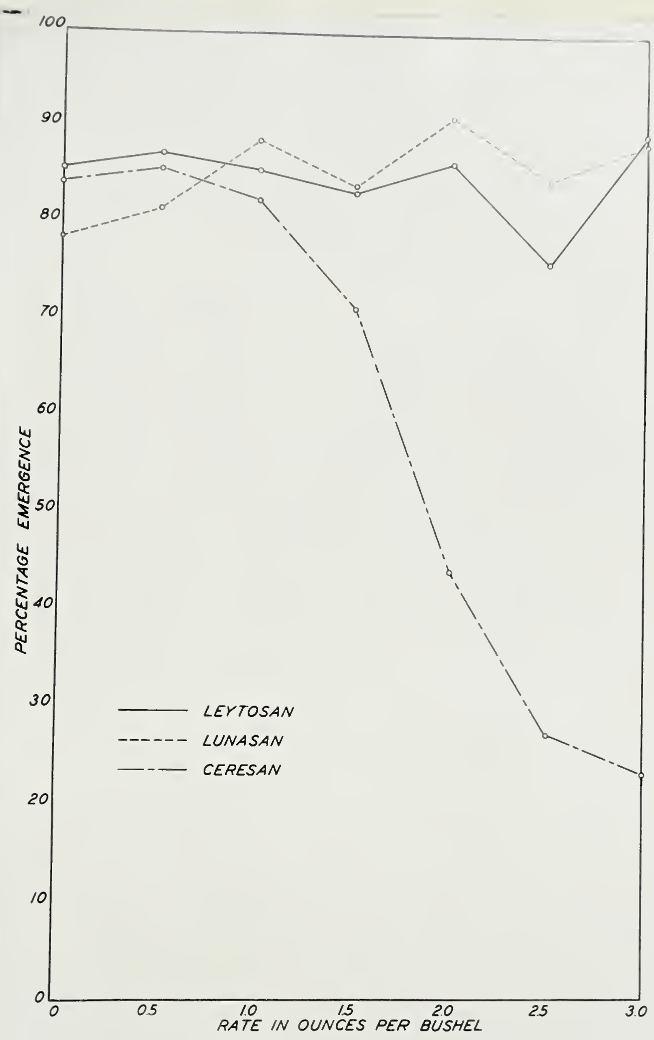


FIGURE V

The relative amount of seed injury in wheat caused by various organic mercury dusts in soil in the greenhouse

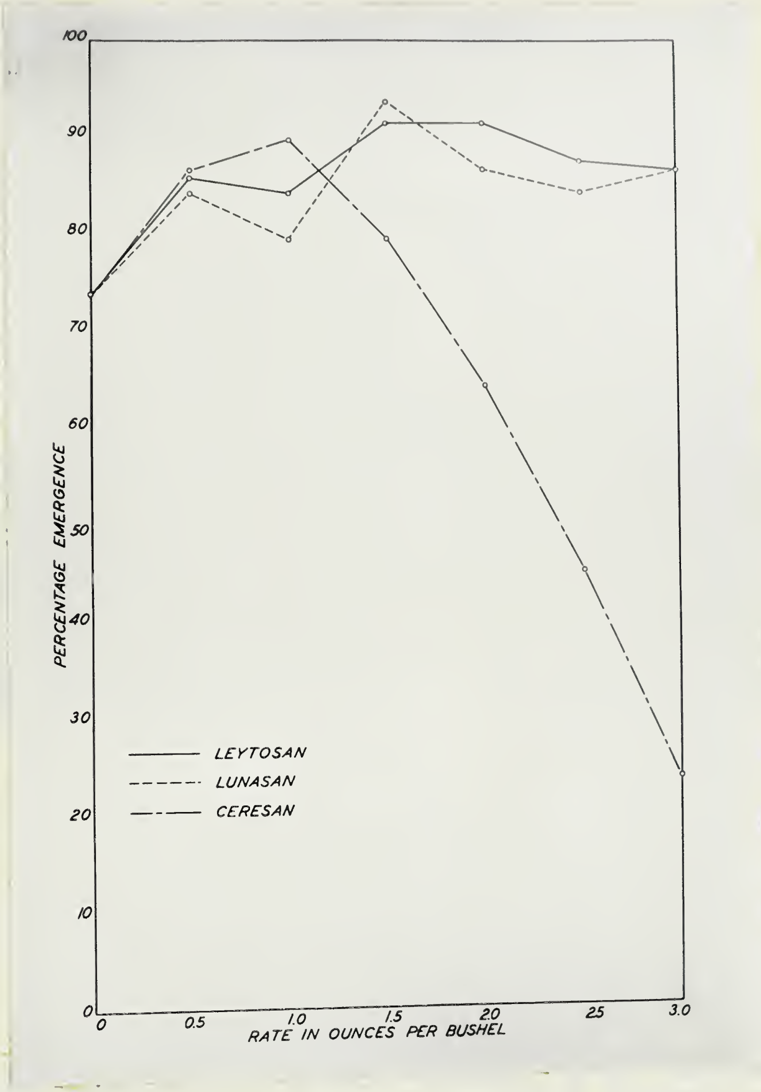


FIGURE VI

The relative amount of seed injury in wheat caused by various organic mercury dusts sown in sand and in soil in the greenhouse

Soil   Sand

Left to right in each group: Lunasan, ½ oz. Leytosan, and Ceresan. Each applied to moist seed at 3 ounces per bushel

<u>Height</u>: The differences due to dusts and media are significant, the latter beyond the 1% point. The first order interactions dealing with rates are significant, showing that the different rates behaved differently for the different media and also for the different dusts. The fact that the plants growing in the soil are significantly higher than those in the sand is obviously due to the presence of a greater nutrient supply. The results for height are essentially the same as for the emergence data.

<u>The Effect of Temperature and Moisture on the Seed Injury Caused by an Organic Mercury Dust</u>

The study of the problems of seed treatment is not complete without a study of the effects of soil temperature and moisture. The contradictory results obtained in the greenhouse and in the field might be explained on the basis of these factors. Dickson (5) reported that an increase in soil temperature up to 28°C increased the rate of germination. Above this, both the germination and the rate of germination decreased rapidly. This was much less noticeable in the treated seed, and there was less growth of moulds. He found soil moisture was not a limiting factor in the germination of wheat, except at the very high and low moisture levels. All treatments except formaldehyde, unless severe, increased the germination at all soil moistures used. Formaldehyde reduced the germination,

especially in the dry soil.

Supper (41) claimed that the type of soil and the water content of the seed bed exercised virtually no influence on the action of Ceresan, abavit B, or Tutan (mercurial compounds). Kirchhoff (22) maintained that, generally speaking, a low soil moisture content (20% of water-holding capacity) resulted in greater injury to germination than a high one (80% of water-holding capacity) and a combination of low temperature and low soil moisture was particularly unfavorable for seed treated with Ceresan. Rabien (37) found seed injury to occur in wheat with abavit B when seed was sown in a cold chamber 0 to 3°C. However, no such injury followed treatment of the seed with Germisan or Tillantin R.

Methods

Seed of the variety Regent was treated as outlined under General Methods. The boxes were waxed to prevent changes in moisture content which might result from absorption or drainage. Each box contained 250 grams of a three to one black loam-sand mixture, 150 grams under the seed and 100 grams covering the seed. The boxes were divided into three lots and made up to soil moisture contents of 18.6, 30.0, and 35.5%, based on oven dry soil. After this, a third of the boxes at each moisture level were placed in each of three cabinets having the following temperatures, 15, 20, and 25°C. For each moisture level,

at each temperature, there were three treatments, viz., 0, $\frac{1}{2}$, and 3 ounces per bushel of the fungicide Ceresan. The moisture content of the boxes was checked each day by weighing each box and adding water when meeded. However, after five days, it was thought that 18.6% moisture was not sufficient to germinate the seeds, so the moisture level was raised to 25%. These boxes were not watered again until the moisture content fell below the original level of 18.6%. After ten days notes were taken on the emergence and plant height.

Results

The summary tables for the percentage emergence and height are presented in Appendix XI. The variance for emergence and height data appears in Tables XXI and XXII, respectively. The results are illustrated in Figures VII, VIII, IX, and X.

TABLE XXI

Variance for emergence data of wheat treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Temperatures	2	47.40	1.71	6.94	18.00
Moisture levels	2	107.20	4.01	6.94	18.00
Rates	2	1194.36	43.13	6.94	18.00
Temperatures x moisture levels	4	22.15	5.04	2.46	3.51
Temperatures x rates	4	27.69	6.31	2.46	3.51
Moisture levels x rates	4	26.74	6.09	2.46	3.51
Temperatures x moisture levels x rates	8	5.83	1.33	2.03	2.69
Error	104	4.39			
Total	134				

Emergence: The differences due to temperature and moisture are not significant. The differences due to rates are highly significant. All the first order interactions are highly significant, which indicates differential response of temperatures, moistures, and rates, i.e. different moisture levels and different temperatures have different actions on the different rates of application, also different moisture levels react differently at different temperatures. These results show that temperature and moisture have no consistent effect on the seed treatment of wheat, but that there is a differential response of rates to both temperature and moisture. The best germination and the least seed injury occurred at the 30% moisture level for each temperature. Figure X shows the marked increase in emergence and height as well as the uniformity of the recommended rate over the check.

TABLE XXII

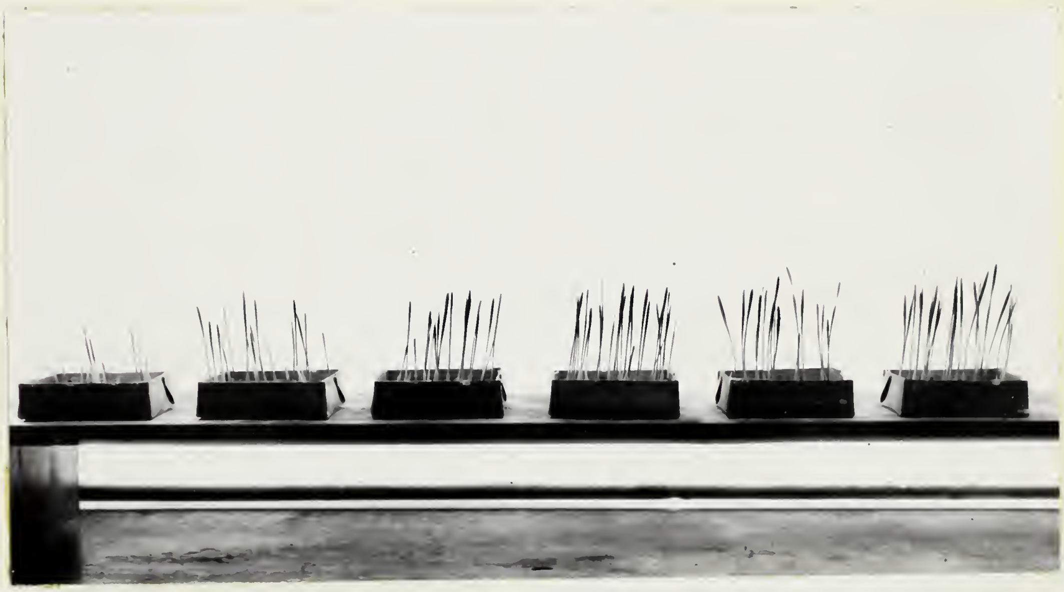
Variance for height data of wheat treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Temperatures	2	625.87	25.64	4.46	8.65
Moisture levels	2	496.21	20.33	4.46	8.65
Rates	2	1660.08	68.01	4.46	8.65
Temperatures x moisture levels	4	7.72	0.32	5.32	11.26
Temperatures x rates	4	80.74	3.31	5.32	11.26
Moisture levels x rates	4	42.15	1.73	5.32	11.26
Temperatures x moisture levels x rates	8	24.41	7.10	2.03	2.69
Error	104	3.44			
Total	134				

FIGURE VII

The effect of soil moisture and temperature on treated and untreated wheat seed

Temperature 15°C



Moisture level

18.6%   30.0%   35.5%

Left to right for each moisture level: untreated; treated with Ceresan ($\frac{1}{2}$ oz.)

FIGURE VIII

The effect of soil moisture and temperature on treated and untreated wheat seed

Temperature 20°C

Moisture level

18.6% 30.0% 35.5%

Left to right for each moisture level: untreated; treated with Ceresan (½ oz.)

FIGURE IX

The effect of soil moisture and temperature on treated and untreated wheat seed

Temperature 25°C

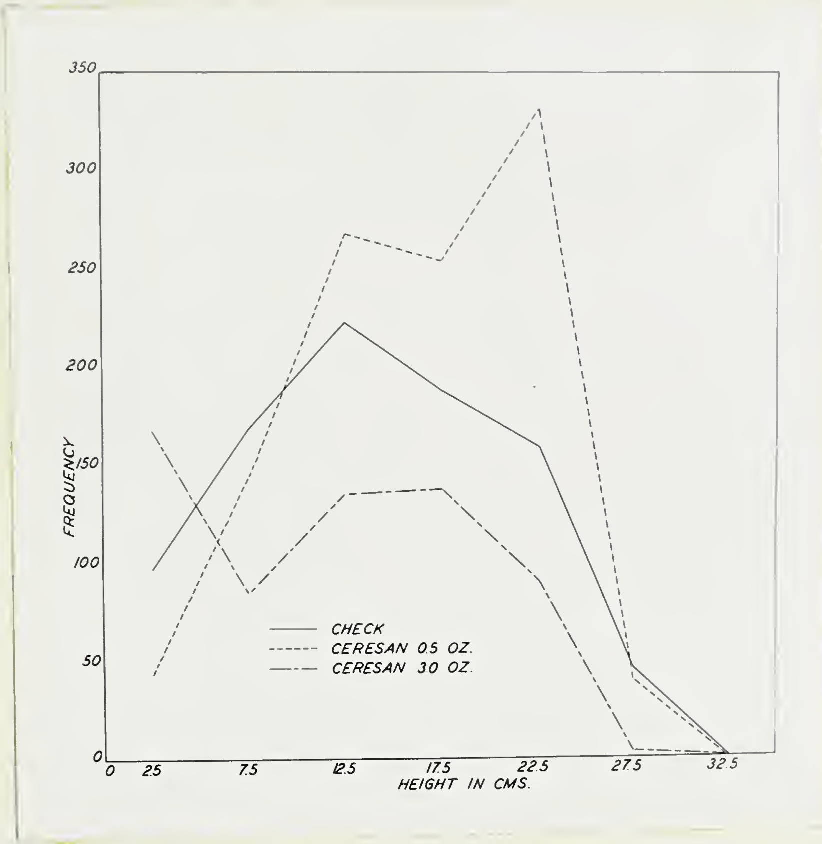
Moisture level

18.6% 30.0% 35.5%

Left to right for each moisture level: untreated; treated with Ceresan (½ oz.)

FIGURE X

The effect of soil moisture and temperature on treated and untreated wheat seed



Frequency polygon of the height data from treated and untreated wheat seed, at all moistures and temperatures

Height: The differences due to temperatures, moisture levels, and rates are all highly significant, while the first order interactions are not significant. This is the exact reverse of the emergence data. The second order interaction is significant beyond the 1% point, showing the differential response and the variability of the height data. The significant influence of temperature and moisture levels shown in the height data is natural because it is known that increased temperature and moisture under normal conditions, up to a certain limit, increase the growth of a plant. The insignificant differences due to the first order interactions show that the various treatments behaved alike under all conditions of temperature and moisture.

THE RELATIVE REACTIONS OF DIFFERENT VARIETIES OF WHEAT TO TREATMENT WITH AN ORGANIC MERCURY DUST

From the information and results obtained in the preceding study, it appeared that Ceresan caused seed injury when applied to moist seed in overdoses. The problem now was to determine whether there was any difference in varietal reaction to treatment with Ceresan.

Introduction

Winkelman (44) in 1932 deemed it advisable to use three cereal varieties in seed treatment studies, in order to exclude irregularities due to a "special constitution" of the seed. Skaptason (39) in 1935 and Leukel (25) in 1936 reported that the extent of formaldehyde injury varies with the different varieties of grain used. Little attention has been given to varietal reaction of wheat to seed treatment with organic mercury dusts. Fischer et al (11) working with wheat in 1938 reported that some varieties differ significantly in their sensitiveness to treatment with organic mercury dusts. In Canada, Mead (28) suggested "the possibility that some varieties of wheat are less easily injured by seed treatment than others is being investigated".

Varietal Reaction of Wheat to Ceresan as Affected by Seed of Different Years

Seed from two consecutive years, 1938 and 1939, was used to determine the varietal reaction. The seed was obtained from the Cereal Division of the University of Alberta and had been grown in the same experiment at the same station each year. The tests were carried out a year

apart, each time several months after harvest. The varieties in the 1938 test were Reward, Marquis, Red Bobs, Garnet, Renown, and Regent and in the 1939 test the same varieties, plus Thatcher and Sikora, were used. Marquis is the oldest of these varieties and has, until recently, occupied the largest part of the wheat acreage of western Canada. Red Bobs, Garnet, and Reward are next in point of age and constitute a fair proportion of the wheat acreage. Garnet and Reward are rapidly being replaced but Red Bobs is increasing in popularity, especially in Alberta. Thatcher, Renown, and Regent are of comparatively recent origin and are increasing in popularity due to their resistance to stem rust. Of these, Thatcher is the most widely grown, particularly in Saskatchewan and Manitoba. Sikora is of importance here only as an experimental variety. The methods were the same in both cases and were carried out as outlined in the General Methods of the preceding investigation. The experiments were made in sand, as it has been shown previously in these studies that seed injury is much more apparent in sand than in soil, chiefly because the protective effect of the organic mercury dust is not operative to the same extent as in soil.

Results for 1938 seed

The summary tables are presented in Appendix XII. The variance for the emergence and height data is shown in Tables XXIII and XXIV, respectively.

TABLE XXIII

Variance for emergence data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	1%
Varieties	5	103.38	11.01	3.70
Rates	6	77.15	8.22	3.47
Varieties x rates	30	9.39	3.38	1.92
Error	162	2.78		
Total	209			

TABLE XXIV

Variance for height data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	1%
Varieties	5	67.87	15.02	3.70
Rates	6	58.79	13.01	3.47
Varieties x rates	30	4.52	4.03	1.92
Error	162	1.12		
Total	209			

Differences due to varieties, rates and varieties x rates in both emergence and height are significant beyond the 1% point. This shows that there is a difference among the varieties tested in their reaction to seed treatment with Ceresan. Marquis and Renown in this case are the extremes the former being the most resistant and the latter the most susceptible. The resistant varieties are Marquis and Red Bobs; the susceptible, Regent and Renown with Reward and Garnet intermediate

in reaction. It should be noted, however, that all varieties showed increased emergence and height when the recommended rate was used. The increases are small due to the fact that the experiment was carried out in sand, where the protective effect of the fungicide is not operative to the same extent as in soil.

Results for 1939 seed

The summary tables are presented in Appendix XIII. The variance for the emergence and height data appears in Tables XXV and XXVI, respectively. Figure XI presents graphically the extremes represented by the varieties, Thatcher, resistant and Regent, susceptible. The height data in this experiment are based on the average emergence in the check boxes. The total height in centimetres for each box in each treatment is divided by the average emergence for the check boxes of that particular variety.

TABLE XXV

Variance for emergence data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	1%
Varieties	7	60.56	6.99	3.29
Rates	6	248.72	28.72	3.29
Varieties x rates	42	8.66	2.84	1.88
Error	220	3.05		
Total	279			

FIGURE XI

The varietal reaction of wheat treated with Ceresan and sown in sand in the greenhouse

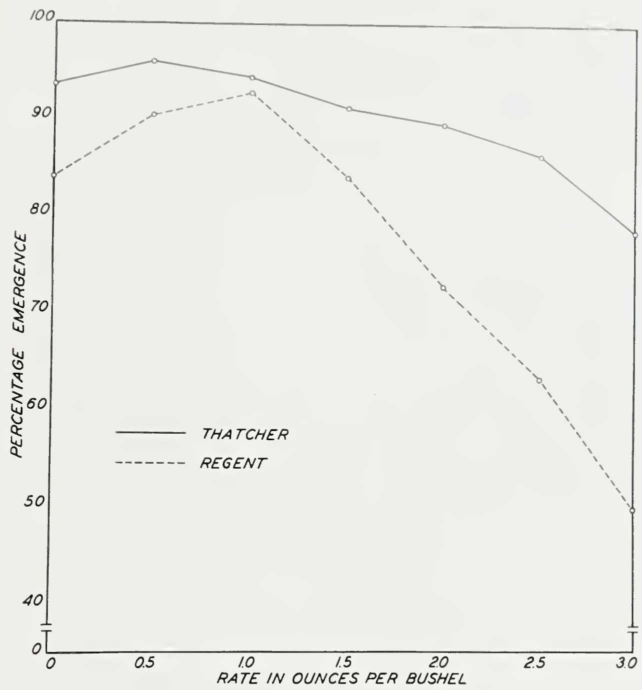


TABLE XXVI

Variance for height data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	1%
Varieties	7	44.18	6.90	3.29
Rates	6	272.72	42.61	3.29
Varieties x rates	42	6.40	2.42	1.88
Error	220	2.64		
Total	279			

The differences due to varieties, rates, and varieties x rates for both emergence and height data are highly significant. This again shows that different varieties react differently to seed treatment with organic mercury dusts. The varieties Marquis, Red Bobs, Thatcher, and Sikora are resistant to seed injury while Regent and Renown are susceptible. Reward and Garnet are still intermediate in reaction. The results also show that seed injury occurs only at the higher rates of application and that both emergence and height are increased at the recommended rate of application.

Varietal Reaction of Wheat to Ceresan as Affected by Storage

A similar experiment, as outlined above, using treated grain left over from the 1938 seed was stored for a month in stoppered flasks at room temperature. It was thought that

such treatment would accentuate the differences between the varieties. The methods used are outlined under General Methods, and in the description of the experiment sown in sand.

Results

The summary tables are presented in Appendix XIV. The variance for the emergence and height data is given in Tables XXVII and XXVIII, respectively. Figure XII illustrates graphically the extremes as shown by Marquis and Renown in this test.

TABLE XXVII

Variance for emergence data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	1%
Varieties	5	526.28	28.98	3.70
Rates	6	1084.07	59.70	3.47
Varieties x rates	30	18.16	4.50	1.92
Error	164	4.04		
Total	209			

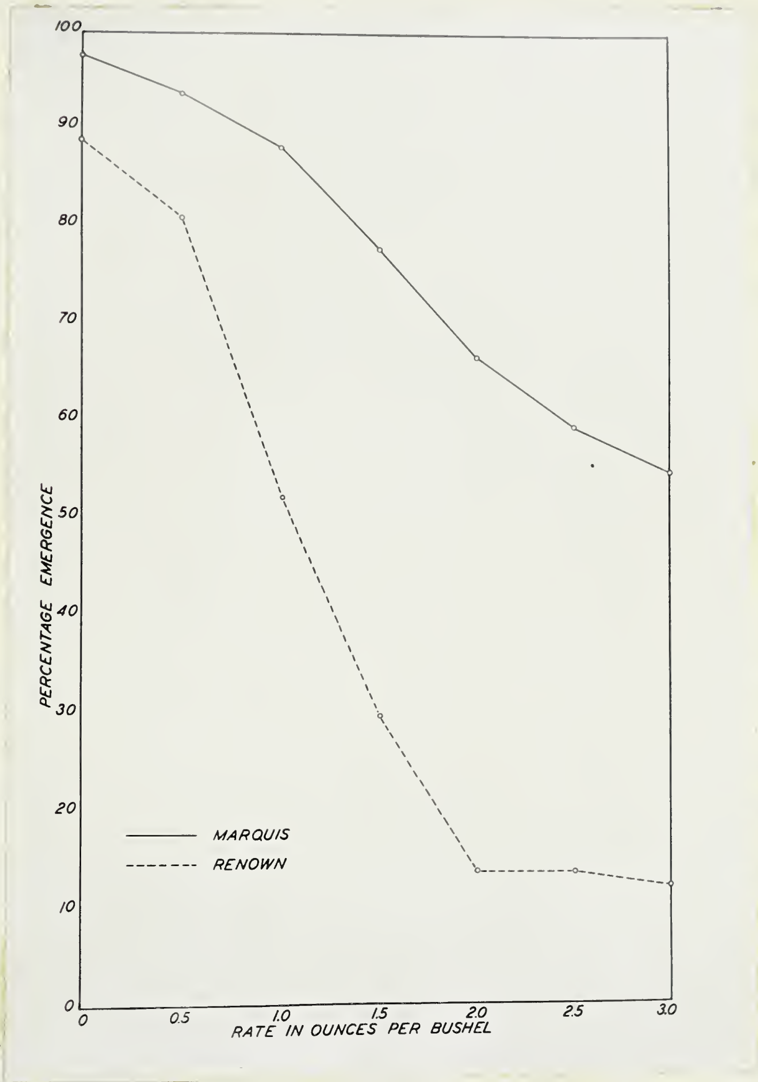
TABLE XVIII

Variance for height data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	1%
Varieties	5	211.39	37.68	3.70
Rates	6	372.94	66.48	3.47
Varieties x rates	30	5.61	2.89	1.92
Error	164	1.94		
Total	209			

FIGURE XII

The varietal reaction of wheat treated with Ceresan and sown in sand in the greenhouse as affected by storage



The differences due to varieties, rates, and varieties x rates in both emergence and height data are highly significant. This shows rather conclusively that there are significant differences between varieties in their reaction to seed treatment with Ceresan. The relative placing of the varieties according to their reaction is the same as for the previous experiment. The recommended rate of application has slightly decreased the emergence and height. It seems advisable, therefore, when moist grain is treated, to sow the seed as soon after treatment as possible.

Varietal Reaction to Ceresan under Field Conditions

Having obtained conclusive results in the greenhouse, it was considered important to determine the relative reaction of the varieties under field conditions. The methods followed were similar to those given under General Methods for field experiments. The seed was from the 1939 crop, and the tests were carried out at two points, Edmonton and Castor.

Edmonton black loam soil

Results

The summary tables are presented in Appendix XV. The variance for emergence and yield appears in Tables

XXIX and XXX, respectively. Figure XIII illustrates graphically the extremes as shown by the varieties Red Bobs and Renown.

TABLE XXIX

Variance for emergence data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	1%
Varieties	7	595.31	7.19	3.29
Rates	6	756.90	9.15	3.29
Varieties x rates	42	82.74	3.91	1.88
Error	220	21.16		
Total	279			

Emergence

The differences due to varieties, rates, and varieties x rates are all highly significant. This verifies the results obtained in the greenhouse, that varieties react differently to seed treatment with Ceresan. The rate averages of Appendix XV show that emergence is significantly increased by treatment with Ceresan.

TABLE XXX

Variance for yield data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Varieties	7	2659.60	61.78	2.34	3.29
Rates	6	399.00	9.27	2.34	3.29
Varieties x rates	42	43.05	0.94	1.57	1.88
Error	220	46.04			
Total	279				

Yield

The differences due to varieties and rates are highly significant, while the interaction of varieties x rates is not significant. The varieties, therefore, according to the yield data, behave alike at the different rates of application. The rate averages of Appendix XV show that the recommended rate of treatment increases the yield significantly.

Castor brown soil

This was a small experiment, using only Marquis and Regent, which had proved to be representative of the extremes in reaction in previous experiments. The summary tables are presented in Appendix XVI. The variance for the emergence and yield data is shown in Tables XXXI and XXXII, respectively.

TABLE XXXI

Variance for emergence data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Varieties	1	546.92	10.46	4.09	7.33
Rates	6	97.76	1.87	2.34	3.30
Varieties x rates	6	72.72	1.39	2.34	3.30
Error	39	52.31			
Total	55				

Emergence

The differences due to varieties are highly significant, while those for rates and varieties x rates are not significant. These results indicate that under field conditions Marquis and Regent react alike to the different rates. The results also show that the danger of seed injury caused by an organic mercury dust is very small under field conditions, if seed is sown soon after treatment.

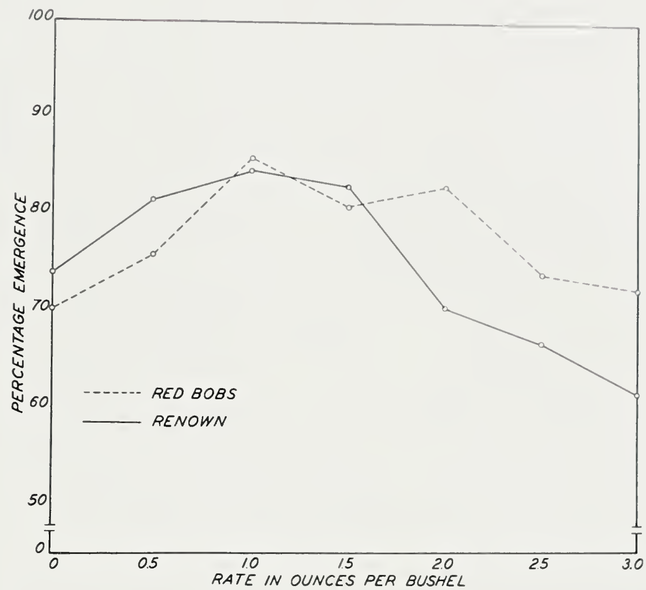
TABLE XXXII

Variance for yield data of various wheat varieties treated with Ceresan

Source of variance	D.F.	Mean square	F	5%	1%
Varieties	1	50.73	2.86	4.09	7.33
Rates	6	13.96	0.79	2.34	3.30
Varieties x rates	6	18.26	1.03	2.34	3.30
Error	39	17.74			
Total	55				

FIGURE XIII

The varietal reaction of wheat treated with Ceresan under field conditions



Yield

The differences due to varieties, rates and varieties x rates are not significant. The results show, therefore, that there is no varietal difference in reaction to seed treatment with Ceresan under the field conditions obtaining in this experiment. The trend, however, is for increased emergence and yield, with no evidence of seed injury from any application of the organic mercury dust used.

Varietal Reactions of Wheat at Different Seed Moisture Levels to Seed Treatment with Ceresan and Formaldehyde under Field Conditions

Since all previous experiments both in the greenhouse and in the field were conducted with moist seed, it was deemed advisable to compare moist with normal seed. At the same time, it was thought that a comparison of an organic mercury dust with formaldehyde might lead to some interesting results. The methods were similar to those outlined under General Methods except that normal as well as moist seed was used. The formaldehyde treatment consisted of dipping the grain in the formaldehyde solutions for two minutes, draining, covering for four hours, and then drying at room temperature before seeding. The con-

centrations of formaldehyde used were 0, 1, 2, 3, 4, 5, and 6 parts of formaldehyde to 320 parts of water.

Results

It was felt that more information could be obtained if the results of the two compounds were analysed separately.

Ceresan

The summary tables are presented in Appendix XVII. The variance for the emergence and yield data appears in Tables XXXIII and XXXIV, respectively.

TABLE XXXIII

Variance for emergence data of various wheat varieties treated with Ceresan at different moisture levels

Source of variance	D.F.	Mean square	F	5%	1%
Varieties	1	1469.01	5.55	161.45	4052.10
Moisture levels	1	907.80	3.43	161.45	4052.10
Rates	6	593.96	3.19	4.28	8.47
Varieties x moisture levels	1	264.69	8.05	5.99	13.74
Varieties x rates	6	15.15	0.46	4.28	8.47
Moisture levels x rates	6	186.42	5.67	4.28	8.47
Varieties x moisture levels x rates	6	32.88	2.21	2.19	2.99
Error	108	14.89			
Total	139				

Emergence

The differences due to varieties, moisture levels and rates are not significant. The first order interactions of

varieties x moisture levels, and moisture levels x rates are significant beyond the 5% point. This shows that the varieties and rates reacted differently at the different moisture levels. The second order interaction, varieties x moisture levels x rates, is barely significant, which indicates that there is considerable variation in the percentage emergence throughout the experiment. These results would no doubt be changed considerably if the number of varieties and moisture levels had been increased. The small number of degrees of freedom makes it almost impossible for them to be significant. The emergence is increased significantly in every case.

TABLE XXXIV

Variance for yield data of various wheat varieties treated with Ceresan at different moisture levels

Source of variance	D.F.	Mean square	F	5%	1%
Varieties	1	1239.69	5.07	161.45	4052.10
Moisture levels	1	736.01	2.01	161.45	4052.10
Rates	6	170.17	1.69	4.28	8.47
Varieties x moisture levels	1	244.46	6.11	3.94	6.90
Varieties x rates	6	51.85	1.30	2.19	2.99
Moisture levels x rates	6	100.76	2.52	2.19	2.99
Varieties x moisture levels x rates	6	42.88	1.07	2.19	2.99
Error	108	40.03			
Total	139				

Yield

These results agree very closely with those of the emergence except that the second order interaction of varieties x moisture levels x rates is not significant, which indicates that there was less variability in the yield data. The summary tables show that the yield is considerably increased and, in many cases, significantly.

Formaldehyde

The summary tables are presented in Appendix XVIII. The variance for the emergence and yield data appears in Tables XXXV and XXXVI, respectively.

TABLE XXXV

Variance for emergence data of various wheat varieties treated with formaldehyde at different moisture levels

Source of variance	D.F.	Mean square	F	5%	1%
Varieties	1	1957.52	13.27	161.45	4052.10
Moisture levels	1	100.31	0.68	161.45	4052.10
Rates	6	15710.62	596.91	2.19	2.99
Varieties x moisture levels	1	147.47	5.60	3.94	6.90
Varieties x rates	6	25.88	0.98	2.19	2.99
Moisture levels x rates	6	32.75	1.24	2.19	2.99
Varieties x moisture levels x rates	6	5.66	0.22	2.19	2.99
Error	108	26.32			
Total	139				

Emergence

The differences due to moisture levels and varieties are not significant. The differences due to rates are so

great that the F value far exceeds the 1% point. The only interaction that is significant is the interaction of varieties x moisture levels, which shows that the varieties reacted differently to the different moisture levels. From other results (19) less seed injury would be expected for the moist seed but this was not the case, the injury being greater than for the dry seed. There is no varietal resistance to formaldehyde injury as shown by this test, which is in contrast to Skaptason's results (39). This is probably due to the difference in the length of time of the treatment. In this experiment the seed was dipped in the various formaldehyde concentrations for two minutes, drained, covered for four hours, and dried, while Skaptason (39) dipped the seed for only fifteen seconds in the various concentrations. The significant point is the marked injurious effect of formaldehyde, as shown by the emergence data, as compared with the non-injurious effect of Ceresan.

TABLE XXXVI

Variance for yield data of various wheat varieties treated with formaldehyde at different moisture levels

Source of variance	D.F.	Mean square	F	5%	1%
Varieties	1	177.87	3.37	3.94	6.90
Moisture levels	1	207.89	3.94	3.94	6.90
Rates	6	8052.77	152.49	2.19	2.99
Varieties x moisture levels	1	59.92	1.13	3.94	6.90
Varieties x rates	6	113.12	2.14	2.19	2.99
Moisture levels x rates	6	59.42	1.12	2.19	2.99
Varieties x moisture levels x rates	6	90.17	1.71	2.19	2.99
Error	108	52.81			
Total	139				

Yield

The differences due to rates are highly significant, and those due to moisture levels are barely significant. None of the interactions is significant, showing that both varieties behaved alike under the different rates of application at the different moisture levels. The important point is the significant reduction in yield at the recommended rate.

DISCUSSION

The application of Ceresan to seed of Kentucky blue grass in an effort to control the leaf spot and foot rot disease proved unsuccessful. The reason for this was that the inoculum was added to the soil instead of to the seed. This was necessary because the pathogen, *Helminthosporium vagans*, does not fruit readily in culture. However, if the disease is naturally seed borne, then the treatment might be beneficial.

The increase in emergence of the treated hulled and hulless timothy seed over that of the check is important when it is considered that a good deal of the commercial timothy seed is hulless. For example, the sample used in these studies was graded as No. 2 grade, No. 1 purity, with approximately 47% hulless seed. The fact that the hulless seed responded to a much greater degree to seed treatment than did the hulled seed compares with the results obtained in the seed treatment of cereals. For instance, wheat responds better to treatment than does either oats or barley; also hulless oats responds much more than hulled oats to seed treatment.

In this case it appears that the treatment of the hulless seed replaces the protective effect given by the lemma and palea in the case of the hulled seed. However,

there still remains a possibility that besides the protective effect of the fungicide there might be a stimulative effect. This has never been proved adequately, in fact, the majority of the evidence appears to point to the protective rather than the stimulative effect.

It is quite evident from these studies that different grasses respond differently to the same treatment. This would indicate that further work should be done, using as many different grasses as possible in order to determine their reaction to chemical seed treatment. It is quite possible that one chemical might produce a greater response than another, which would mean that a large number of chemicals should be experimented with.

Common talc, which is usually considered to be an inert material, appeared to increase the emergence of both hulled and hulless timothy seed as well as crested wheat grass seed. This is the opposite of Youden's (45) findings while working with powdered growth promoting substances mixed in talc. He found that the emergence of treated wheat and soybean seed was reduced, and attributed this to the detrimental effect of the talc.

Temperature in these studies had no consistent influence on the seed treatment of hulless timothy seed. This, however, is far from conclusive evidence and much more extensive work needs to be done. Even in these results,

the maximum emergence for the different treatments occurred at different temperatures. It is suggested that further experiments be conducted to include different grasses and treatments over a wide range of soil temperatures and moistures.

The results show that the organic mercury dust, Ceresan, is more injurious than ½ oz. Leytosan or Lunasan when applied in overdoses to moist wheat under greenhouse conditions. The margin of safety in concentrations is at least 100%. The field tests, which proved contradictory to the greenhouse results, show that there is little danger to wheat from the organic mercury dusts tested, even when applied in overdoses to moist seed. These results agree with those recently published by Dillon Weston and Brett (7).

The effects of temperature and moisture were not consistent enough to explain the contradictory results obtained from the greenhouse and field. However, the fact that the least seed injury occurred at a moisture level of 30% based on an oven dry soil, is a plausible explanation. The seed in the field experiment was sown under very favorable conditions for germination and growth. The soil moisture taken about the time the seed was sown was approximately 30%, based on an oven dry soil, which corresponds with the moisture content of the soil in the

controlled greenhouse test. It is difficult to say whether seed injury resulting from organic mercury dusts would be serious in the field if growth conditions were unfavorable. On the basis of the controlled soil temperature and moisture test, it appears safe to conclude that there would be no seed injury at the recommended rate of application. One of the most interesting findings from the controlled soil temperature and moisture experiment was that the greatest beneficial effect with the organic mercury dust Ceresan was obtained under high temperature and low moisture soil conditions. As a contrast it has been shown that under low moisture conditions formaldehyde produces its greatest injury to the seed (18).

Although the results of the greenhouse experiments show conclusively that there are differences in varietal reaction of wheat to Ceresan, such differences are only apparent under very abnormal conditions, e.g. when overdoses are applied to moist seed. The same is true, but to a lesser degree, for the field experiment as indicated by the emergence data of Appendix XV, It is, therefore, probable that with normal seed, treated at the recommended rate, under average field conditions, such differences in varietal reaction would not occur.

One of the more important points brought out by these experiments with organic mercury dusts is that when the recommended rates are used and the seed is planted

immediately following treatment, there is no seed injury. However, there is a danger of seed injury occurring if the treated moist seed is for any reason kept too long in storage, as has been previously reported by Hanna (16) and Koehler (23).

The beneficial effect of using organic mercury dusts on healthy seed is well brought out in Tables XXXVII and XXXVIII and in Figure XIV.

TABLE XXXVII
Summary of all greenhouse tests using Ceresan

Rate in ounces per bushel	% emergence	Height in cms.
0	84.0	15.6
½	90.1	17.0
1	88.9	16.6
1½	87.4	15.9
2	81.0	14.9
2½	73.9	13.3
3	68.0	12.0

The above table shows the results of treating wheat with different amounts of Ceresan under greenhouse conditions. The figures were obtained from four experiments containing eight different varieties and consisting of twenty replicates. It shows definitely an increase in emergence and height at the recommended rate of application, as well as the margin of safety.

TABLE XXXVIII

Summary of all field experiments using Ceresan

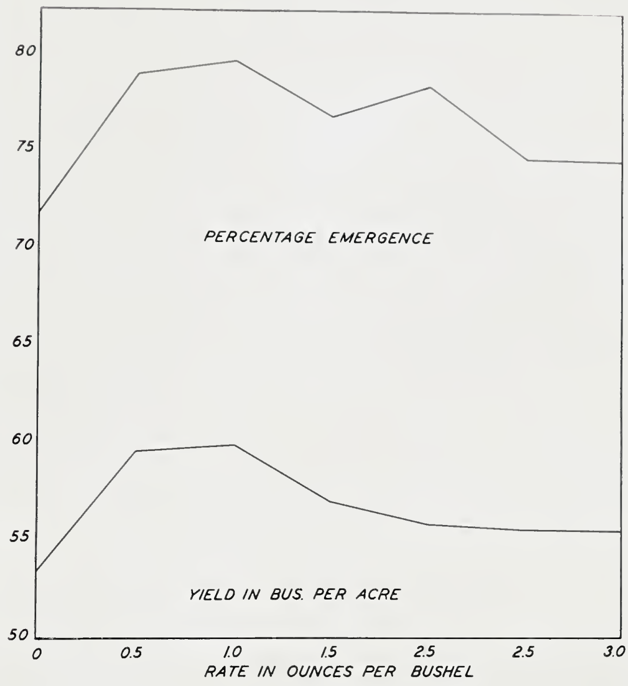
Rate in ounces per bushel	% emergence	Yield in bushels per acre
0	71.9	53.4
½	79.2	59.6
1	79.9	59.9
1½	77.0	57.0
2	78.6	55.8
2½	74.9	55.6
3	74.8	55.5

Table XXXVIII shows the results of treating wheat with different amounts of Ceresan under field conditions. The figures were obtained from four experiments containing eight different varieties, carried out at two different stations and comprising nineteen replicates. This table shows that under field conditions there was a consistent increase in both emergence and yield for all applications. These results are shown graphically in Figure XIV.

It is known that formaldehyde causes considerable seed injury to wheat. This is well illustrated in the rate averages of Appendix XVIII. At the recommended rate of 1-320, the emergence is reduced 18% and the yield is reduced 8.5 bushels per acre. However, if we compare the rate averages of Appendix XVIII with those of Appendix XVII, which are the results of the Ceresan rates from the

FIGURE XIV

The effect of seed treatment with Ceresan on the emergence and yield of wheat under field conditions



same experiment, the difference between the emergence values is 29% and between the yield values is 14 bushels per acre at the recommended rates of application. This almost doubles the loss which a farmer may experience if he uses formaldehyde rather than Ceresan.

There still remains the possibility that, under field conditions adverse for germination, the results might be entirely different.

In a previous experiment using controlled soil temperature and moisture conditions, it was shown that a moist soil tended to reduce the amount of seed injury caused by overdoses of an organic mercury fungicide like Ceresan. The conditions prevailing during the time the field experiments were being sown might have had a similar effect. Table XXXIX gives the maximum and minimum temperature of the air and the precipitation for the month of May, 1940. The maximum and minimum soil temperatures cover only the latter half of the month. These figures cover the periods, of approximately two weeks duration, before and after seeding. The soil moisture at the time of sowing was approximately 30% on an oven dry basis.

TABLE XXXIX

Temperature and precipitation for May, 1940

Date	Air °F Maximum	Air °F Minimum	Soil °F Maximum	Soil °F Minimum	Precipitation
1	62	34			---
2	68	43			.01
3	55	46			trace
4	60	35			trace
5	58	41			.04
6	61	37			.28
7	59	39			trace
8	60	36			trace
9	68	38			---
10	79	45			---
11	66	50			trace
12	63	43			trace
13	62	39			.02
14	66	40			.01
15	68	43	62	55	.03
16	59	47	60	49	trace
17	68	39	65	46	---
18	78	48	74	53	.12
19	67	51	67	59	---
20	72	41	73	53	---
21	78	50	77	59	---
22	85	45	81	57	---
23	89	48	84	61	---
24	86	55	84	63	---
25	72	50	71	59	trace
26	63	45	68	58	---
27	56	43	60	51	.11
28	67	34	71	47	.57
29	66	45	72	53	.27
30	68	48	71	56	.48
31	46	46	57	48	.30
Average	66.9	43.0	70.4	54.5	Total 2.24 inches

This table, therefore, provides a plausible explanation of the results obtained. It will be observed that the conditions prevailing in the field during the time of germination, May 17 to May 31, are comparable to those of the controlled temperature and moisture test which gave the least seed injury from Ceresan.

Such observations as have been made indicate that the increase in emergence and yield resulting from seed treatment with organic mercury dusts is due to seed protection rather than to a direct stimulation to plant growth. It appears that convincing evidence of stimulation is not forthcoming (29, 34, 46). Miles (29) also reported that in laboratory trials the growth rate of seedlings from treated seed exceeds by from 5 to 20% that of those from the controls which are commonly overrun by moulds. Other workers who have reported significant increases in emergence and yield of clean, healthy seed grain are Morwood (30), Koehler (23), and Porter (36). The increases in yield were as high as 10% for oats and 5% for wheat.

On the basis of these experimental data, it would seem that seed treatment of wheat with organic mercury dusts is good agricultural practice and that there is no danger of seed injury to moist seed if the seed is sown immediately following treatment, whereas normal seed can be

stored without injury for several weeks following treatment as has been demonstrated here and in other laboratories.

SUMMARY

1. There has been very little reported in the literature on the chemical seed treatment of grasses.

2. The work was conducted mainly with the idea of improving the germination and stands of several grasses by means of various chemicals such as Ceresan, $\frac{1}{2}$ oz. Leytosan, Lunasan, Sulfanilamide, etc.

3. Chemical seed treatment of Kentucky blue grass and crested wheat grass failed to increase the germination.

4. The leaf spot and foot rot disease of Kentucky blue grass caused by <u>Helminthosporium vagans</u> was not controlled effectively by Ceresan, in an experiment in which the inoculum was added to the soil.

5. Ceresan and $\frac{1}{2}$ oz. Leytosan markedly increased the germination of hulless timothy seed, while only Ceresan increased the germination of the hulled timothy seed.

6. Talc, used as a diluent in these studies and usually considered to be an inert material, tended to increase the germination of hulled and hulless timothy seed and

crested wheat grass seed but not that of Kentucky blue grass.

7. Temperature had little effect on the response of hulless timothy seed to treatment with Ceresan.

8. Ceresan is much more likely to cause seed injury than ½ oz. Leytosan or Lunasan when applied at excessive rates to moist seed, especially under greenhouse conditions.

9. Temperature and moisture appeared to have no direct significant effect on the response of wheat to seed treatment with Ceresan, but there is the possibility of an indirect effect.

10. Varieties of spring wheat reacted differently to seed treatment with Ceresan. Overdoses caused least injury to Marquis, Red Bobs, Thatcher, Sikora, and Canus, while Regent and Renown were seriously injured, with Reward and Garnet intermediate.

11. The varietal differences were distinguished in the greenhouse on the basis of emergence and height, and in the field on the basis of emergence and yield.

12. In these studies, treatment of normal healthy wheat with organic mercury dusts--Ceresan, ½ oz. Leytosan, and Lunasan--increased the emergence and height in greenhouse experiments, and emergence and yield in the field

when applied at the recommended rates. The plants from treated seed appeared more uniform and vigorous.

13. Formaldehyde treatment of wheat seed caused serious seed injury resulting in decreased emergence and yield.

14. No seed injury occurred when organic mercury dusts were applied at recommended rates to moist seed and the seed sown immediately. However, treated moist seed was injured when stored for a month after treatment, as has been demonstrated by other workers.

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APPENDIX I

The effect of various concentrations of Ceresan applied at different rates on the emergence of Kentucky blue grass

Rate	Check	0%	1%	2%	3%	4%	5%
1-50	19.3	15.5	22.0	18.0	19.8	19.8	19.5
1-100		22.8	24.2	22.8	21.8	26.0	22.8
1-300		17.8	19.0	20.8	23.5	24.2	24.0
1-600		17.0	20.2	18.0	18.8	21.8	20.8
1-1000		19.0	16.8	19.0	17.0	22.0	21.2

Minimum significant difference 4.02%

Concentration averages

% concentration	% emergence
0	18.4
1	20.4
2	19.7
3	20.2
4	22.8
5	21.7

Minimum significant difference 1.79

Rate averages

Rate	% emergence
1-50	19.1
1-100	23.4
1-300	21.6
1-600	19.4
1-1000	19.2

Minimum significant difference 1.64

APPENDIX II

The effect of various concentrations of Ceresan applied at different rates on the emergence of crested wheat grass

Rate	Check	0%	1%	2%	3%	4%	5%
1-50	52.4	57.5	50.5	46.8	46.0	46.5	40.2
1-100		52.5	45.8	51.8	50.5	52.0	47.5
1-300		51.5	51.8	44.5	45.8	49.8	48.0
1-600		59.2	54.8	49.0	50.2	43.0	50.5
1-1000		50.2	55.0	54.2	46.5	49.5	55.2

Minimum significant difference 7.07%

Concentration averages

% concentration	% emergence
0	54.2
1	51.6
2	49.3
3	47.8
4	48.2
5	48.3

Minimum significant difference 4.46

Rate averages

Rate	% emergence
1-50	47.9
1-100	50.0
1-300	48.6
1-600	51.1
1-1000	51.8

Minimum significant difference 4.07

APPENDIX III

The effect of various concentrations of Ceresan applied at different rates to hulless timothy seed on emergence

Rate	Check	0%	1%	2%	3%	4%	5%
1-50	25.2	33.2	64.2	20.8	6.8	1.2	0.2
1-100		39.8	77.8	68.5	43.5	22.0	16.5
1-300		40.0	71.8	77.2	81.8	71.8	64.0
1-600		41.2	56.0	70.5	73.0	79.8	78.8
1-1000		34.8	46.5	64.0	66.5	62.5	77.2

Minimum significant difference 11.17%

Concentration averages

% concentration	% emergence
0	37.8
1	63.3
2	60.2
3	54.3
4	47.5
5	47.3

Minimum significant difference 23.94

Rate averages

Rate	% emergence
1-50	21.1
1-100	44.7
1-300	67.8
1-600	66.6
1-1000	58.6

Minimum significant difference 21.89

APPENDIX IV

The effect of various concentrations of Ceresan applied at different rates to hulled timothy seed on emergence

Rate	Check	0%	1%	2%	3%	4%	5%
1-50	81.2	86.0	88.8	32.0	11.0	1.8	0.2
1-100		85.8	91.8	87.5	60.8	40.8	19.5
1-300		89.2	94.8	95.5	94.2	95.0	93.0
1-600		80.8	91.5	91.5	95.5	92.5	92.8
1-1000		82.5	89.0	93.0	91.2	95.0	90.0

Minimum significant difference 6.51%

Concentration averages

% concentration	% emergence
0	84.9
1	91.2
2	89.9
3	70.5
4	65.0
5	59.1

Minimum significant difference 26.81

Rate averages

Rate	% emergence
1-50	36.6
1-100	64.4
1-300	93.6
1-600	90.8
1-1000	90.1

Minimum significant difference 24.51

APPENDIX V

The effect of various concentrations of $\frac{1}{2}$ oz. Leytosan applied at different rates to hulless timothy seed on emergence

Rate	Check	0%	1%	2%	3%	4%
1-50	29.5	29.0	61.2	59.2	68.8	72.2
1-100		31.8	41.2	62.8	68.5	68.8
1-300		24.5	36.8	36.5	43.0	54.2
1-600		25.5	29.0	50.0	25.0	45.5
1-1000		32.0	36.0	39.5	43.0	24.8

Minimum significant difference 20.43%

Concentration averages

% concentration	% emergence
0	28.6
1	40.8
2	49.6
3	49.7
4	55.1

Minimum significant difference 12.56

Rate averages

Rate	% emergence
1-50	58.1
1-100	54.6
1-300	39.0
1-600	35.0
1-1000	35.1

Minimum significant difference 12.56

APPENDIX VI

The effect of various concentrations of ½ oz. Leytosan applied at different rates to hulled timothy seed on emergence

Rate	Check	0%	1%	2%	3%	4%
1-50	78.9	78.5	88.0	90.2	72.8	44.5
1-100		83.2	82.8	91.2	77.0	83.0
1-300		84.2	76.0	81.8	89.8	80.8
1-600		79.8	79.2	78.8	86.8	83.5
1-1000		79.8	84.0	82.8	78.0	76.8

Minimum significant difference 10.66%

Concentration averages

% concentration	% emergence
0	81.1
1	82.0
2	85.0
3	80.9
4	73.7

Minimum significant difference 9.42

Rate averages

Rate	% emergence
1-50	74.8
1-100	83.4
1-300	82.5
1-600	81.6
1-1000	80.3

Minimum significant difference 9.42

APPENDIX VII

The effect of temperature on treated and untreated hulless timothy seed

Treatment	Temperature °C	% emergence
Check	10	32.2
	15	39.6
	20	33.2
	25	35.6
	30	26.2
3% Ceresan 1-300	10	68.2
	15	74.4
	20	70.8
	25	86.6
	30	63.6

Minimum significant difference 7.04

Treatment averages

Treatment	% emergence
Check	33.4
Treated	72.7

Minimum significant difference 5.87

Temperature averages

Temperature	% emergence
10°C	50.2
15°C	57.0
20°C	52.0
25°C	61.1
30°C	44.9

Minimum significant difference 9.32

APPENDIX VIII

Relative effects of three organic mercury dusts on wheat under greenhouse conditions

	New Improved Ceresan			½ oz. Leytosan			Lunasan		
Rate in ounces per bushel	% emergence	Height in cms.	% injured seeds	% emergence	Height in cms.	% injured seeds	% emergence	Height in cms.	% injured seeds
0	80.4	14.5	3.6	80.4	14.5	3.6	80.4	14.5	3.6
½	87.6	13.8	2.8	89.2	16.0	0.0	91.2	16.7	0.4
1	80.4	13.3	4.8	90.8	16.4	1.6	87.2	16.9	1.2
1½	63.2	11.5	10.0	84.8	16.6	1.2	89.2	16.7	2.0
2	58.0	9.2	8.0	86.0	16.5	3.6	86.8	17.1	2.0
2½	40.8	7.2	38.0	86.4	15.9	4.8	84.8	16.4	3.2
3	34.0	5.9	44.4	79.2	13.9	8.4	78.8	14.9	6.4

APPENDIX VIII (continued)

Dust averages

Dust	% emergence	Height in cms.	% injured
Ceresan	63.6	10.8	17.2
½ oz. Leytosan	85.2	15.7	3.2
Lunasan	85.6	16.2	2.8

Rate averages

Rate in ounces per bushel	% emergence	Height in cms.	% injured seeds
0	80.4	14.5	3.6
½	89.2	15.5	1.2
1	86.0	15.5	2.4
1½	79.2	14.9	4.4
2	76.8	14.3	8.0
2½	70.8	13.2	15.2
3	64.0	11.6	19.6

APPENDIX IX

Relative effects of three organic mercury dusts on wheat grown in the field

Rate in ounces per bushel	Ceresan % emergence	Ceresan Yield in bushels per acre	½ oz. Leytosan % emergence	½ oz. Leytosan Yield in bushels per acre	Lunasan % emergence	Lunasan Yield in bushels per acre
0	78.4	82.7	71.9	79.8	75.5	83.6
½	82.3	95.8	82.7	84.6	82.6	77.2
1	86.8	93.3	82.8	86.7	82.6	91.4
1½	78.8	87.4	82.2	83.7	77.2	85.7
2	81.6	81.3	81.0	85.1	85.1	87.8
2½	79.5	87.3	82.9	81.8	84.9	81.3
3	86.4	89.8	84.6	91.3	70.1	84.7

Minimum significant difference for emergence = 7.45%

Minimum significant difference for yield = 12.19 bushels

APPENDIX IX (continued)

Dust averages

Dust	% emergence	Yield in bushels per acre
Ceresan	82.0	88.2
$\frac{1}{2}$ oz. Leytosan	81.2	84.7
Lunasan	79.7	84.5
Minimum significant difference	4.46	4.60

Rate averages

Rate in ounces per bushel	% emergence	Yield in bushels per acre
0	75.3	82.0
$\frac{1}{2}$	82.5	85.9
1	84.1	90.5
$1\frac{1}{2}$	79.4	85.6
2	82.6	84.7
$2\frac{1}{2}$	82.4	83.5
3	80.4	88.6
Minimum significant difference	6.83	7.04

APPENDIX X

Relative effects of three organic mercury dusts on wheat grown in the greenhouse in soil and sand

	New Improved Ceresan				$\frac{1}{2}$ oz. Leytosan				Lunasan			
	Soil		Sand		Soil		Sand		Soil		Sand	
Rate oz/bu	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.
0	73.6	17.9	84.0	17.2	73.6	16.8	85.6	17.5	73.6	17.4	78.4	18.1
$\frac{1}{2}$	86.4	22.8	85.6	17.5	85.6	21.2	87.2	19.0	84.0	21.5	81.6	19.2
1	89.6	20.5	82.4	16.5	84.0	22.2	85.6	18.3	79.2	20.5	88.8	19.1
$1\frac{1}{2}$	79.2	18.6	71.2	12.4	91.2	23.6	83.2	17.4	93.6	23.7	84.0	17.3
2	64.0	13.6	44.0	7.6	91.2	23.1	86.4	18.0	86.4	22.8	91.2	20.2
$2\frac{1}{2}$	44.8	9.8	27.2	4.3	87.2	23.1	76.0	17.2	84.0	20.9	84.8	19.1
3	23.2	3.9	23.2	3.4	86.4	22.8	89.6	18.1	86.4	22.2	88.8	18.9

Minimum significant difference for emergence = 9.76%

Minimum significant difference for height = 2.38 cms.

APPENDIX X (continued)

Dust averages

Dust	% emergence	Height in cms.
Ceresan	62.7	13.3
½ oz. Leytosan	85.2	19.9
Lunasan	84.6	20.1
Minimum significant difference	14.36	3.60

Rate averages

Rate in ounces per bushel	% emergence	Height in cms.
0	78.1	17.5
½	85.1	20.2
1	84.9	19.5
1½	83.7	18.8
2	77.2	17.6
2½	67.3	15.7
3	66.2	14.9
Minimum significant difference	25.64	6.42

Medium averages

Medium	% emergence	Height in cms.
Soil	78.4	19.5
Sand	76.6	16.0
Minimum significant difference	4.08	1.28

APPENDIX XI

The effect of soil temperature and moisture on the reaction of wheat to seed treatment with an organic mercury dust

	15°C						20°C						25°C					
	18.6%		30.0%		35.5%		18.6%		30.0%		35.5%		18.6%		30.0%		35.5%	
Rate oz/bu	% emergence	Height in cms.	% emergence	Height in cms.	% emergence	Height in cms.	% emergence	Height in cms.	% emergence	Height in cms.	% emergence	Height in cms.	% emergence	Height in cms.	% emergence	Height in cms.	% emergence	Height in cms.
0	84.8	8.1	91.2	13.0	85.6	14.2	78.4	11.3	86.4	17.4	80.0	19.7	48.8	6.6	81.6	18.7	73.6	19.8
½	95.2	10.5	97.6	14.9	96.0	16.6	99.2	17.5	96.8	23.9	95.2	25.2	95.2	23.0	98.4	26.7	94.4	28.6
3	48.0	3.7	62.4	6.2	52.8	5.8	49.6	7.2	64.0	10.9	64.0	10.5	33.6	9.1	64.8	11.6	59.2	12.5

Minimum significant difference for emergence = 10.56%

Minimum significant difference for height = 2.33 cms.

APPENDIX XI (continued)

Temperature averages

Temperature °C	% emergence	Height in cms.
15	79.3	10.3
20	79.3	16.0
25	72.2	17.4
Minimum significant difference	8.84	2.08

Moisture averages

% moisture	% emergence	Height in cms.
18.6	70.3	10.8
30.0	82.6	15.9
35.5	77.9	17.0
Minimum significant difference	8.68	2.08

Rate averages

Rate in ounces per bushel	% emergence	Height in cms.
0	78.9	14.3
½	96.4	20.7
3	55.4	8.6
Minimum significant difference	8.84	2.08

APPENDIX XII

Varietal reaction of wheat to Ceresan based on treatments of 1938 seed

	Reward			Marquis			Red Bobs			Garnet			Renown			Regent		
Rate oz/bu	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured
0	92.8	14.2	0.8	93.6	15.5	1.6	94.4	16.9	0.8	90.4	14.3	1.6	89.6	13.7	6.4	80.0	14.8	7.2
½	94.4	15.6	0.0	95.2	16.3	0.0	95.2	17.0	3.2	90.4	13.7	1.6	91.2	14.3	4.0	83.2	15.4	4.0
1	89.6	14.5	2.4	99.2	15.0	0.0	100.0	16.7	0.0	90.4	14.2	1.6	89.6	13.2	5.6	84.8	13.9	9.6
1½	91.2	14.4	4.8	96.0	15.7	0.8	97.6	16.9	0.8	89.6	14.2	1.6	88.8	13.1	8.0	80.8	13.7	8.8
2	80.8	13.5	12.0	89.6	13.6	7.2	98.4	16.0	0.0	91.2	14.6	3.2	82.4	12.4	9.6	73.6	12.8	12.8
2½	84.0	13.4	9.6	91.2	14.4	7.2	93.6	15.7	4.8	88.0	12.9	4.8	84.8	10.8	13.6	60.0	10.0	25.6
3	72.0	12.0	17.6	88.0	13.2	8.8	87.2	13.9	7.2	72.8	10.8	16.0	52.8	6.7	40.8	72.8	11.1	20.8

Minimum significant difference for emergence = 15.52%

Minimum significant difference for height = 2.69 cms.

APPENDIX XII (continued)

Variety averages

Variety	% emergence	Height in cms.	% injured seeds
Reward	86.4	13.9	6.8
Marquis	93.2	14.8	3.6
Red Bobs	95.2	16.2	2.4
Garnet	87.6	13.5	4.4
Renown	82.8	12.0	12.4
Regent	76.4	13.1	12.8
Minimum significant difference	5.84	1.02	

Rate averages

Rate in ounces per bushel	% emergence	Height in cms.	% injured seeds
0	90.0	14.9	3.2
$\frac{1}{2}$	91.6	15.4	2.0
1	92.4	14.6	3.2
$1\frac{1}{2}$	90.4	14.7	4.0
2	86.0	13.8	7.6
$2\frac{1}{2}$	83.6	12.9	10.8
3	74.4	11.3	18.4
Minimum significant difference	6.20	1.08	

APPENDIX XIII

Varietal reaction of wheat to Ceresan based on treatments of 1939 seed

	Reward		Regent		Garnet		Renown		Thatcher		Red Bobs		Marquis		Sikora	
Rate oz/bu	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.	% emerg-ence	Height in cms.
0	84.0	15.5	84.0	14.6	84.8	16.1	88.0	16.0	93.6	15.6	88.8	15.3	93.6	16.5	84.0	15.2
½	96.8	18.9	90.4	17.2	92.0	18.6	92.0	16.5	96.0	15.3	96.0	16.9	96.8	15.5	94.4	18.1
1	93.6	17.4	92.8	16.5	83.2	17.6	92.8	15.7	94.4	14.2	94.4	16.5	97.6	16.7	92.0	18.4
1½	91.2	15.5	84.0	13.9	86.4	17.5	87.2	14.2	91.2	14.2	91.2	15.2	92.8	14.7	91.2	17.6
2	84.8	14.1	72.8	11.5	85.6	16.0	64.8	10.2	89.6	13.3	93.6	14.9	91.2	14.8	88.0	14.0
2½	74.4	11.4	63.2	10.0	72.0	11.4	62.4	9.5	86.4	12.1	73.6	11.0	77.6	11.2	84.0	14.9
3	68.8	10.5	49.6	7.6	70.4	11.4	48.8	7.0	78.4	11.0	70.4	11.1	74.4	10.4	77.6	13.4

Minimum significant difference for emergence = 7.56%

Minimum significant difference for height = 3.20 cms.

APPENDIX XIII (continued)

Variety averages

Variety	% emergence	Height in cms.
Reward	84.8	14.8
Regent	76.7	13.0
Garnet	82.0	15.5
Renown	76.6	12.7
Thatcher	89.9	13.7
Red Bobs	86.8	14.4
Marquis	89.1	14.2
Sikora	87.3	15.9
Minimum significant difference	4.44	1.35

Rate averages

Rate in ounces per bushel	% emergence	Height in cms.
0	87.6	15.6
½	94.3	17.1
1	92.6	16.6
1½	89.4	15.4
2	83.8	13.6
2½	74.2	11.4
3	67.4	10.3
Minimum significant difference	5.24	1.13

APPENDIX XIV

The effect of storage on the varietal reaction of wheat to Ceresan

	Reward			Marquis			Red Bobs			Garnet			Renown			Regent		
Rate oz/bu	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured	% emerg-ence	Height in cms.	% in-jured
0	91.2	14.8	4.0	97.6	16.3	0.8	96.0	14.9	0.8	91.2	14.0	4.0	88.8	12.9	6.4	74.4	11.7	14.4
½	89.6	15.1	4.0	93.6	15.0	4.0	96.0	15.4	0.8	88.0	16.3	3.2	80.8	11.1	14.4	80.8	13.2	9.6
1	65.6	11.0	25.6	88.0	13.7	8.8	79.2	11.7	16.8	72.8	11.0	20.8	52.0	6.8	44.8	52.0	7.7	36.8
1½	43.2	8.7	44.8	77.6	11.9	20.0	77.6	12.7	14.4	49.6	10.0	41.6	29.6	4.7	59.2	24.8	4.5	63.2
2	33.6	6.9	52.8	66.4	11.0	24.8	61.6	9.3	28.0	40.0	7.0	49.6	13.6	2.9	71.2	23.2	5.0	62.4
2½	37.6	6.4	52.8	59.2	9.8	30.4	61.6	9.3	28.8	32.8	6.1	54.4	13.6	2.9	75.2	19.2	3.9	64.0
3	26.4	5.1	59.2	54.4	9.9	35.2	52.0	7.9	43.2	40.8	7.2	43.2	12.0	2.9	67.2	12.8	2.9	62.4

Minimum significant difference for emergence = 8.68%

Minimum significant difference for height = 3.00 cms.

APPENDIX XIV (continued)

Variety averages

Variety	% emergence	Height in cms.	% injured seeds
Reward	55.3	9.7	34.7
Marquis	76.7	12.5	17.7
Red Bobs	74.9	11.6	19.0
Garnet	59.3	10.2	31.0
Renown	41.5	6.3	48.3
Regent	41.0	7.0	44.7
Minimum significant difference	6.96	1.13	

Rate averages

Rate in ounces per bushel	% emergence	Height in cms.	% injured seeds
0	89.9	14.1	5.1
½	88.1	14.4	6.0
1	68.3	10.3	25.6
1½	50.4	8.8	40.5
2	39.7	7.0	48.1
2½	37.3	6.4	50.9
3	33.1	6.0	51.7
Minimum significant difference	7.52	1.22	

APPENDIX XV

Varietal reaction of wheat to Ceresan under field conditions at Edmonton

Rate oz/bu	Marquis % emergence	Marquis Yield in bu/ac	Red Bobs % emergence	Red Bobs Yield in bu/ac	Reward % emergence	Reward Yield in bu/ac	Garnet % emergence	Garnet Yield in bu/ac	Regent % emergence	Regent Yield in bu/ac	Renown % emergence	Renown Yield in bu/ac	Thatcher % emergence	Thatcher Yield in bu/ac	Canus % emergence	Canus Yield in bu/ac
0	84.1	59.6	70.2	56.9	77.2	38.4	73.0	43.1	74.9	49.2	74.0	45.6	81.9	54.0	83.7	69.7
½	91.5	53.3	75.8	62.2	79.0	42.3	76.3	53.1	76.7	55.6	81.4	50.3	81.9	62.3	87.2	69.8
1	88.5	57.4	85.9	64.1	78.1	42.2	80.2	53.8	84.0	59.8	84.5	52.0	86.9	60.6	88.1	69.3
1½	84.9	51.2	80.8	61.6	80.7	44.0	78.0	46.0	81.6	54.9	82.9	45.6	82.6	61.4	86.1	70.4
2	88.4	54.3	82.8	66.4	80.8	46.5	79.3	49.8	72.4	48.5	70.4	45.1	78.5	56.3	84.1	70.6
2½	82.6	53.6	73.8	57.9	81.9	39.4	79.2	50.8	74.8	52.0	66.8	38.3	82.7	52.1	79.8	63.1
3	72.4	49.0	72.3	57.1	74.0	37.0	66.4	41.7	58.2	46.5	61.5	37.2	80.7	53.6	82.5	64.3

Minimum significant difference for emergence = 11.50%

Minimum significant difference for yield = 8.30 bushels.

APPENDIX XV (continued)

Variety averages

Variety	% emergence	Yield in bushels per acre
Marquis	84.6	54.0
Red Bobs	77.4	60.9
Reward	78.8	41.4
Garnet	76.0	48.3
Regent	74.6	52.3
Renown	74.5	44.9
Thatcher	82.2	57.2
Canus	84.5	68.2
Minimum significant difference	3.44	3.14

Rate averages

Rate in ounces per bushel	% emergence	Yield in bushels per acre
0	77.4	52.1
½	81.2	56.1
1	84.5	57.4
1½	82.2	54.4
2	79.6	54.7
2½	77.7	50.9
3	71.0	48.3
Minimum significant difference	4.07	2.93

APPENDIX XVI

Varietal reaction of wheat to Ceresan under field conditions at Castor

Rate in ounces per bushel	Marquis % emergence	Marquis Yield in bushels per acre	Regent % emergence	Regent Yield in bushels per acre
0	60.2	26.7	50.9	21.7
½	66.1	28.3	61.0	22.6
1	58.4	24.5	55.2	26.0
1½	58.8	28.2	53.4	26.2
2	62.6	28.9	65.4	27.2
2½	60.9	26.4	54.4	26.5
3	66.8	27.3	49.8	26.8

Minimum significant difference for emergence = 10.23%

Minimum significant difference for yield = 5.94 bushels

APPENDIX XVI (continued)

Variety averages

Variety	% emergence	Yield in bushels per acre
Marquis	62.0	27.2
Regent	55.7	25.4
Minimum significant difference	3.86	2.24

Rate averages

Rate in ounces per bushel	% emergence	Yield in bushels per acre
0	55.6	24.2
½	63.6	25.4
1	56.8	25.2
1½	56.1	27.2
2	64.0	28.0
2½	57.6	26.4
3	58.3	27.0
Minimum significant difference	7.23	4.21

APPENDIX XVII

Varietal reaction of wheat to Ceresan as affected by
the moisture content of the seed

	Marquis				Regent			
	Normal		14% moisture		Normal		14% moisture	
Rate in ounces per bushel	% emergence	Yield in bushels per acre	% emergence	Yield in bushels per acre	% emergence	Yield in bushels per acre	% emergence	Yield in bushels per acre
0	76.9	48.6	84.3	53.5	72.9	62.6	71.2	54.0
½	92.3	54.1	92.8	59.5	89.3	67.7	85.2	63.9
1	94.3	62.1	93.5	58.5	90.9	69.3	87.9	64.5
1½	94.8	53.3	91.9	54.6	89.4	64.8	86.8	62.6
2	95.0	62.4	89.5	53.3	90.3	62.6	81.0	57.9
2½	91.3	59.3	84.4	50.7	87.2	68.1	76.4	52.9
3	92.0	58.1	83.8	54.4	90.5	63.1	67.1	51.8

Minimum significant difference for emergence = 4.86%

Minimum significant difference for yield = 8.00 bushels

APPENDIX XVII (continued)

Variety averages

Variety	% emergence	Yield in bushels per acre
Marquis	89.8	55.9
Regent	83.3	61.8
Minimum significant difference	5.48	5.27

Moisture level averages

Moisture	% emergence	Yield in bushels per acre
Normal	89.1	61.2
14% moisture	84.0	56.6
Minimum significant difference	5.48	5.27

Rate averages

Rate in ounces per bushel	% emergence	Yield in bushels per acre
0	76.3	54.7
$\frac{1}{2}$	89.9	61.3
1	91.6	63.6
$1\frac{1}{2}$	90.7	58.8
2	89.0	59.0
$2\frac{1}{2}$	84.8	57.8
3	83.4	56.8
Minimum significant difference	8.64	6.36

APPENDIX XVIII

Varietal reaction of wheat to formaldehyde as affected by the moisture content of the seed

	Marquis				Regent			
	Normal		14% moisture		Normal		14% moisture	
Rate	% emergence	Yield in bushels per acre	% emergence	Yield in bushels per acre	% emergence	Yield in bushels per acre	% emergence	Yield in bushels per acre
0	80.6	49.8	81.0	58.7	75.7	56.8	75.6	57.6
1-320	64.9	47.0	62.9	41.4	57.6	51.1	55.2	49.2
2-320	34.7	32.1	35.7	24.4	25.9	23.6	26.9	25.2
3-320	45.9	35.0	43.0	34.0	35.8	35.8	29.7	24.8
4-320	16.5	14.0	17.7	15.4	11.2	11.3	7.6	6.2
5-320	9.0	8.8	11.3	10.7	8.6	10.2	0.5	0.3
6-320	8.4	9.8	5.3	3.9	1.6	0.9	0.3	0.4

Minimum significant difference for emergence = 6.46%

Minimum significant difference for yield = 9.15 bushels

APPENDIX XVIII (continued)

Variety averages

Variety	% emergence	Yield in bushels per acre
Marquis	36.9	27.5
Regent	29.4	25.2
Minimum significant difference	4.09	2.45

Moisture level averages

Moisture	% emergence	Yield in bushels per acre
Normal	34.0	27.6
14% moisture	32.3	25.2
Minimum significant difference	4.09	2.45

Rate averages

Rate	% emergence	Yield in bushels per acre
0	78.2	55.7
1-320	60.2	47.2
2-320	30.8	26.3
3-320	38.6	32.4
4-320	13.2	11.7
5-320	7.4	7.5
6-320	3.9	3.8
Minimum significant difference	3.23	4.60